Principal Locations of Metal Loading from Flood-Plain Tailings, Lower Silver Creek, Utah, April 2004

Prepared in cooperation with the
UTAH DEPARTMENT OF ENVIRONMENTAL QUALITY, DIVISION OF WATER QUALITY

Scientific Investigations Report 2007–5248

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Cover photo: Metal-rich, acidic water draining away from piles of tailings along the flood plain of Silver Creek, Utah. Photograph taken looking southeast in April 2004 by Briant A. Kimball.

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DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

Contents

Figures

Tables

Conversion Factors, Datum, and Abbreviated Water-Quality Units

Multiply	By	To obtain
Length		
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
Area		
square kilometer (km²)	247.1	acre
Volume		
liter (L)	0.264	gallon (gal)
milliliter (mL)	0.000264	gallon (gal)
microliter (μL)	0.000000264	gallon (gal)
Flow rate		
liter per second (L/s)	15.85	gallon per minute (gal/min)
Mass flow		
milligram per second (mg/s)	0.1905	pound avoirdupois per day (lb/day)
kilogram per day (kg/day)	2.205	pound avoirdupois per day (lb/day)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32.$$

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Chemical concentration and water temperature are reported only in metric units. Chemical concentration is reported in milligrams per liter (mg/L), micrograms per liter (μg/L), or millimoles per liter (mM/L). Milligrams per liter is a unit expressing the mass of solute per unit volume (liter) of water. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is reported in microsiemens per centimeter at 25 degrees Celsius (μS/cm).

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Abstract

Because of the historical deposition of mill tailings in flood plains, the process of determining total maximum daily loads for streams in an area like the Park City mining district of Utah is complicated. Understanding the locations of metal loading to Silver Creek and the relative importance of these locations is necessary to make science-based decisions. Application of tracer-injection and synoptic-sampling techniques provided a means to quantify and rank the many possible source areas. A mass-loading study was conducted along a 10,000-meter reach of Silver Creek, Utah, in April 2004. Mass-loading profiles based on spatially detailed discharge and chemical data indicated five principal locations of metal loading. These five locations contributed more than 60 percent of the cadmium and zinc loads to Silver Creek along the study reach and can be considered locations where remediation efforts could have the greatest effect upon improvement of water quality in Silver Creek.

Introduction

In heavily mined watersheds, numerous tailings and waste-rock piles may occur that can be sources of metals and acidity to streams. The challenge facing those interested in improving water quality is thus one of source determination: in a given watershed, what sources of water are most detrimental to stream-water quality and how do they compare? Source determination also is particularly important in the Total Maximum Daily Load (TMDL) process because individual sources must be identified, and their relation to the total load from all sources must be quantified.

In response to the source-determination question, an approach has been developed within the U.S. Geological Survey (USGS) Toxic Substances Hydrology Program to quantify mass loading associated with various sources (Kimball and others, 2002). This approach combines the methods of tracer dilution to quantify discharge and synoptic sampling to provide spatially detailed chemical information. Given discharge and chemical data, profiles of mass loading illuminate the principal locations where sources contribute metals and acid to a stream. The purpose of this investigation was to identify the principal locations of metal mass loading to Silver Creek in Summit County, Utah (fig. 1), a tributary to the Weber River, to provide information for the Silver Creek TMDL process for the Utah Department of Environmental Quality, Division of Water Quality (UDEQ).

The mass-loading approach was employed by the USGS to quantify mass loading of metals to Silver Creek along a 10,000-m study reach that is listed on Utah's 303(d) list as being impacted by zinc and cadmium (Michael Baker Jr., Inc., 2004; Utah Department of Administrative Services, 2005). A reconnaissance mass-loading study in the southern portion of lower Silver Creek identified substantial loading of metals to Silver Creek, but the analysis only quantified the net loading; it did not give details about the location of particular sources in this portion of lower Silver Creek (Kimball and others, 2004). Almost all of these tailings occur in the flood plain of Silver Creek, and thus they are commonly called "flood-plain" tailings.

Purpose and Scope

The purpose of this report is to document the principal locations of metal mass loading to Silver Creek, Utah. This report (1) characterizes the chemistry of stream water and inflows along the Silver Creek study reach, (2) quantifies the metal loading along the study reach, and (3) identifies the principal locations where metal loading occurs. These results will facilitate science-based decisions about targets for remediation.

Description of the Study Area

This study addresses the reach of Silver Creek from the U.S. Highway 40 overpass to the Interstate 80 overpass, a reach of almost 10,000 m (fig. 1). Silver Creek originates upstream from Park City, Utah (to the southwest of the area in fig. 1), and flows into the Weber River near Wanship, Utah (to the northeast of the area in fig. 1). This has been called the southern portion of the lower Silver Creek site by UDEQ in their Innovative Assessment (Ann Tillia, Utah Department of Environmental Quality, written commun., 2005). USGS
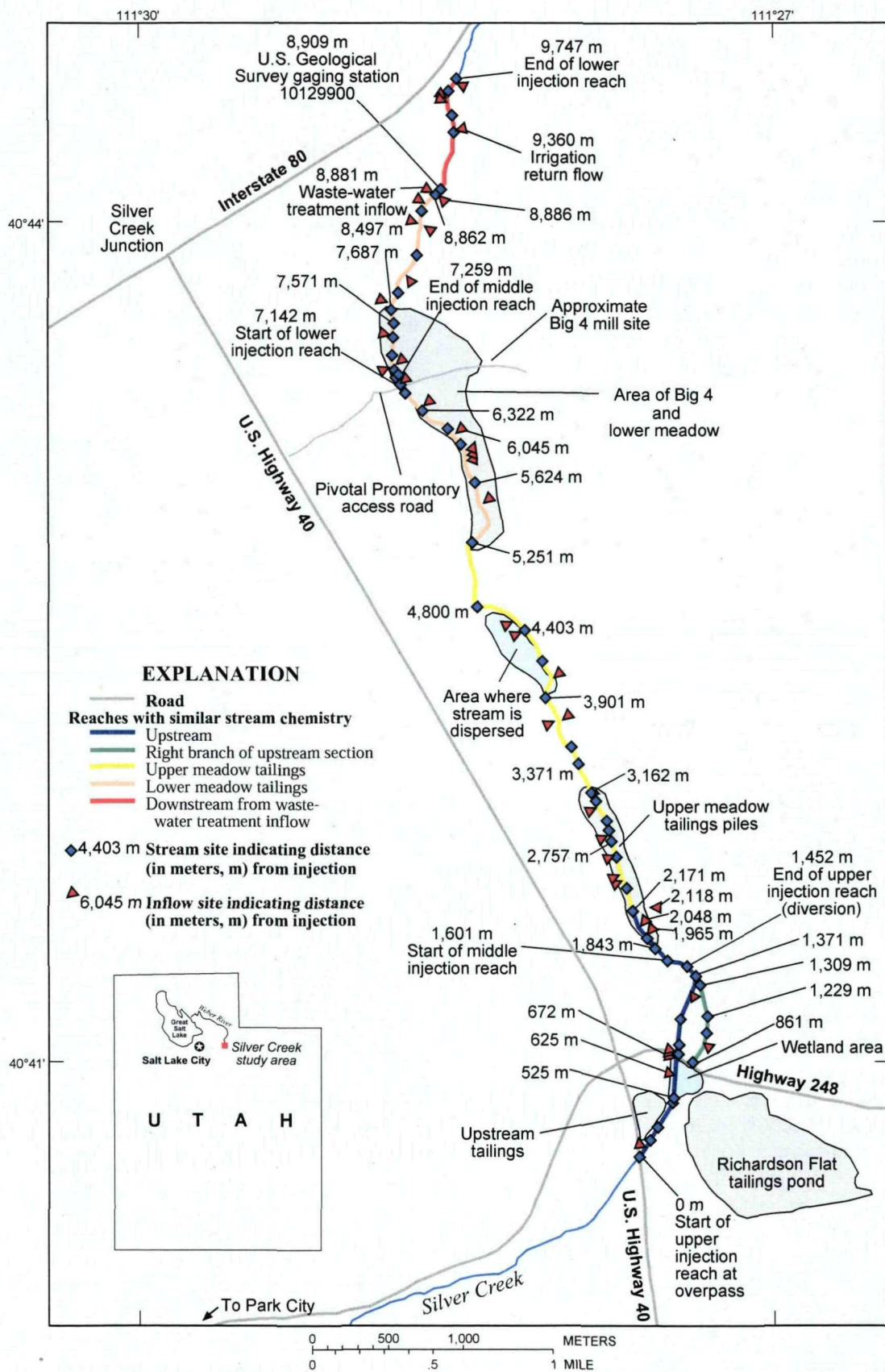
Figure 1.   Location of the study reach indicating upper, middle, and lower injection reaches, location of changes in stream-water chemistry (colors indicate classification by cluster analysis), and principal locations of tailings, Silver Creek, Utah, April 2004.

discharge-gaging station 10129900, Silver Creek near Silver Creek Junction, Utah, is located near the end of the study reach and measures flow from a drainage area of 45 km². The flow measured at the gage includes discharge from a waste-water treatment plant (WWTP) located just upstream from the gage (fig. 1).

Timing of the sampling was planned so that samples would reflect stream-water quality under snowmelt runoff conditions because Silver Creek can be ephemeral along this study reach during typical low-flow periods. Mean annual discharge at the gaging station is 82 L/s, based upon discharge records for 2002 through 2004, which were all years with drought conditions (Tibbetts and others, 2004; Wilkowske and others, 2003). Monthly mean discharge varies from a low of 44 L/s in September to a high of 206 L/s in March. April has a monthly mean discharge of 167 L/s at the stream gage; this value and that from March are a result of snowmelt runoff. Most of the discharge at the gage during low-flow months is from discharge of the WWTP. Upstream from the WWTP, which is most of the study reach, Silver Creek can be ephemeral.

Diversions of Silver Creek required that the 10,000-m study reach be divided into three injection reaches for the study (fig. 1). The upper injection reach (from 0 to 1,452 m) contained a wetland area that started downstream from 525 m. Silver Creek discharges from the wetland into two branches that flow under Highway 248 through two separate culverts. The two branches converge again upstream from 1,371 m, allowing for an accounting of discharge at the end of the upper injection reach. For the stream sites between 525 m and 1,371 m, no discharge estimate was possible. The upper injection reach included two important locations for flood-plain tailings. An area just downstream from the start of the study reach is locally referred to as the "flood-plain" tailings, but has been labeled "upstream tailings" in figure 1 (fig. 2A). At Richardson Flat, a tailings pond is separated from direct contact with Silver Creek by an earthen dam.

During recent periods of drought, discharge at 1,452 m usually has been diverted down the valley in an irrigation ditch along the east side of the Silver Creek valley. For the purposes of this study, some of the water was allowed back into the natural channel of Silver Creek at 1,452 m to provide continuous discharge along the entire middle injection reach (1,601 to 7,259 m). Because the study occurred at the end of the snowmelt period in Silver Creek, this was a diversion into a channel that had not been dry for a substantial period of time. Thus, the diverted flow was not adsorbed by a dry alluvial channel. Much of the channel contained flow before the diversion, but continuous discharge in the natural channel was necessary to join all the ground-water inflows and to quantify loading from the ground-water discharge along the middle injection reach. In the meadow area, from 1,601 m to 7,142 m, two principal areas contain visible tailings piles; upper areas from 1,843 m to about 3,162 m; and a lower area from 5,251 m to 7,142 m. Tailings in both the upper and lower meadow areas are present in piles (mounds, berms, and

hummocks) along the stream that could have been created in preparation for shipping to be reprocessed (Ann Tillia, Utah Department of Environmental Quality, written commun., 2005). Vegetation around the tailings is very scarce; the mounds are mostly bare. A typical inflow from mounds of tailings in the upper meadow area is shown in figure 2B. Ground-water discharge from the lower meadow area is shown in figure 2C.

The lower injection reach (7,142 to 9,747 m) contained continuous discharge as a result of the ground-water discharge upstream in the middle injection reach. Tailings from the operation of the Old Big 4 mill, which was located near the present Pivotal Promontory access road, contribute metals to the lower tailings area. Additional tailings farther downstream also contribute metals (figs. 1 and 2D). This lower reach also receives discharge from the WWTP as well as return flow at 9,360 m from the irrigation ditch that starts at 1,452 m in the upper injection reach.

Details of the ore deposits in the Park City district have been discussed by Garmoe and Erickson (1968) and Bromfield (1989). Because the study reach is affected by tailings from the ore processing, the mineralogy of the ore deposits is the most important aspect of these reports. Sphalerite (ZnS) is the principal ore mineral contributing zinc. Cadmium commonly substitutes for zinc in sphalerite; thus, this mineral is the principal source of cadmium as well. Additionally, some of the ores occurred as skarn deposits, which are hosted in carbonate rocks. Carbonate minerals, especially rhodochrosite ($MnCO_3$), also occurred as gangue minerals in the intrusions (Rockwell and others, 1999). Thus, tailings from these ores should have abundant sphalerite and carbonate rhodochrosite.

Previous Work

A reconnaissance of this same study reach by Kimball and others (2004) included stream discharge and chemistry for four locations. These locations were upstream and downstream from Richardson Flat, and upstream and downstream from the WWTP. Loads of cadmium and zinc increased downstream between each of these four sampling locations. At the time of that study (Kimball and others, 2004), discharge from Silver Creek was completely diverted into an irrigation ditch, and there was no continuous flow in the natural channel. Numerous ground-water discharges from tailings in the meadow area were observed, but the amount of mass loading from the various inflows was not quantified. At the sampling site upstream from the WWTP, the ground-water discharge had combined to create continuous flow in the channel.

Information from the study area has been compiled for a TMDL study (Michael Baker Jr., Inc., 2004). As with the USGS reconnaissance, however, there was little detail on sources within the meadow area. Another USGS study (Giddings and others, 2001) identified elevated metal concentrations in bed sediments of Silver Creek. The elevated

Figure 2.   Photographs of major sources of metal loading along the study reach, Silver Creek, Utah, April 2004. (A) Looking upstream toward injection point under the Highway 40 bridge and the "upstream" tailings; (B) Looking upstream while sampling an inflow draining from mounds of tailings in the upper meadow tailings area; (C) Looking upstream at the pond at the end of the lower meadow tailings area, upstream from Pivotal Promontory access road; and (D) Looking upstream at tailings in the flood plain downstream from historical Old Big 4 mill site.

concentrations extended all the way from the Park City area to the mouth of Silver Creek.

Acknowledgments

Methods for Mass-Loading Approach

A mass-loading approach to identify sources of metals combines several methods. Details of these methods are reported elsewhere (Kimball and others, 2002; Kimball and others, 2004; Kimball and others, 2006b; Kimball and others, 2006a), but some aspects are repeated here to help understand the results for Silver Creek. Data collection for the approach is based on field methods of tracer dilution (Kilpatrick and Cobb, 1985) and synoptic sampling (Bencala and McKnight, 1987). Data analysis is based on methods of calculating loads to obtain detailed longitudinal profiles of mass loading (Kimball and others, 2002; Kimball and others, 2003). Also, multivariate sample-classification methods help to interpret the detailed chemical results.

Tracer Injection and Synoptic Sampling

The mass-loading study began with a careful evaluation of inflows along the study reach, which was accomplished by walking the entire study reach (fig. 1). Before flow was diverted into the middle injection reach, ground-water inflows were evident, and their cumulative effect created some perennial discharge by the end of the middle injection reach. Stream sites for synoptic sampling were chosen upstream and downstream from the inflows to allow mass-balance calculations. Additional stream sites were located along the study reach at regular intervals to check for dispersed, subsurface inflow to the stream. Sampling sites for the synoptic study are referenced by the measured distance along the study reach in a downstream direction, with the injection site assigned a distance of 0 m. Inflows are referred to as left and right bank with an orientation looking downstream. Reference to a stream segment means the section of the study reach between two consecutive stream sites, and is referenced by both the upstream and downstream distances, for example the segment 1,601–1,843 m.

A continuously injected chemical tracer provides a way to measure discharge that includes the hyporheic flow of the stream because it follows the water as it moves in and out of the streambed. Under ideal conditions, tracer-dilution techniques allow the detection of increases in discharge of only a few percent. Once the tracer reaches a steady concentration at each point along the stream, called the plateau condition, discharge can be calculated at any stream point from the concentration of the tracer at that point. This typical application of a tracer-injection study was adequate for the upper and lower injection reaches, but for the middle injection reach the approach was modified.

Sodium bromide was selected for the injection solution because of the high pH of the stream. No geologic sources of bromide were suspected in the watershed (Nichols and Bryant, 1990). In the analysis of this experiment, bromide is assumed to be a conservative tracer. No adverse effects on organisms were observed from the injection of the tracer solution. Details of the three tracer injections are provided in table 1, and the system of pumps and controls is detailed in Kimball and others (2004).

The background concentration of the tracer was much lower than the concentration of injected tracer in the stream and was mostly uniform. With these uniform background

Table 1. Details of tracer injections for three injection reaches along Silver Creek, Utah, April 2004.

[L/s, liters per second; mg/L, milligrams per liter]

Injection reach	Injection start		Synoptic start		Synoptic end		Injection end		Injection rate (L/s)	Tracer-injectate concentration (mg/L as bromide)	Background bromide concentration (mg/L)
	Date	Time	Date	Time	Date	Time	Date	Time			
Upper	4/14/2004	12:00	4/15/2004	9:07	4/15/2004	13:25	4/15/2004	11:00	0.00123	159,600	0.24
Middle	4/8/2004	9:00	4/9/2004	8:55	4/9/2004	14:12	4/9/2004	15:00	.00100	162,800	.31
Lower	4/5/2004	15:27	4/6/2004	9:34	4/6/2004	14:00	4/6/2004	15:50	.00251	160,300	.31

concentrations, stream discharge at any location downstream from the injection is given by:

$$Q_D = \frac{Q_{INJ} C_{INJ}}{C_D - C_B} \qquad (1)$$

where:

Q_D is the stream discharge at the downstream site, in L/s,

Q_{INJ} is the injection rate (table 1), in L/s,

C_{INJ} is the injectate concentration, in mg/L,

C_D is the tracer concentration at a downstream site, in mg/L, and

C_B is the naturally occurring tracer concentration, in mg/L.

The amount of tracer dilution between two consecutive stream sites indicates the total inflow from surface and ground water for that segment of the study reach. Tracer dilution accounts for visible inflows, such as tributaries and springs, as well as dispersed, subsurface inflow. No separate measurement was made of tributary inflow to be able to divide the total inflow volume between surface- and ground-water components for a given stream segment.

Synoptic samples were collected at numerous stream and inflow locations after the bromide concentration reached a steady-state plateau. Sampled inflows were mostly small springs and some irrigation return flows; only one well-defined tributary occurred at 9,562 m. A complete listing of sampling locations, sample information, and the chemical data are provided in tables 2, 3, and 4 (located at back of report). Samples were collected in 1.8-L HPDE bottles usually by submersing the neck of each bottle into the water near the center of flow. Samples were transported to a central processing area where 125-mL aliquots were prepared for cation and anion analyses. Onsite processing included filtration and pH measurement. Filtration was completed with in-line capsule disk filters with an effective pore size of 0.45-μm (FA samples). Some total-recoverable samples (RA) were collected to evaluate the presence of colloidal concentrations of metals. The colloidal concentration was calculated as the difference between the RA and FA concentration for those samples that included both. Both FA and RA aliquots for cation analysis were acidified to a pH of less than 2.0 with ultrapure nitric acid. Total recoverable and dissolved cation concentrations were determined from unfiltered and filtered samples, respectively, by using inductively coupled argon plasma-mass spectrometry. Cation concentrations are reported for aluminum, arsenic, barium, calcium, cadmium, cobalt, chromium, copper, iron, potassium, magnesium, manganese, molybdenum, sodium, nickel, lead, silica (as silicon), silver, strontium, uranium, vanadium, and zinc. Dissolved anion concentrations were determined from filtered, unacidified samples by ion chromatography. Anion concentrations are reported for chloride, bromide, and sulfate.

Alkalinity (as calcium carbonate) was determined by titration from filtered, unacidified samples.

Load Calculation

Three specific load calculations are used to quantify the sources of loading to Silver Creek. First, the tracer injection provides estimated discharge (Q) and synoptic sampling provides constituent concentrations (C), which are combined to determine sampled instream load:

$$M_A = C_A Q_A (0.0864) \qquad (2)$$

where:

M_A is the constituent load, or mass flux, at location A, in kg/day,

C_A is the concentration of the selected constituent at location A, in mg/L,

Q_A is the discharge at location A, in L/s, and

0.0864   is the conversion factor from mg/s to kg/day.

Sampled instream load for stream sites was calculated from the filtered concentration (FA sample) of the constituent. The longitudinal profile of sampled instream load is the basic result from the mass-loading study.

The second load calculation determines the net change in mass load in one stream segment, and is used to determine if the load of a given constituent increases or decreases in the given segment. For the change in load for the segment starting at location A and ending at location B, we calculate:

$$\Delta M_{B-A} = M_B - M_A \qquad (3)$$

where:

ΔM_{B-A} is the change in sampled instream load from locations A to B, in kg/day,

M_B is the constituent load at location B, in kg/day, and

M_A is defined in equation 2.

Gains in constituent load (ΔM_{B-A} is greater than zero) imply that there is a source that contributes to the stream between the two stream sites. Instream load also can decrease within a stream segment (ΔM_{B-A} is less than zero), meaning that there was a net loss of the constituent from physical, chemical, or biological processes. Summing all the increases in load between sampling sites along the study reach (positive values of ΔM_{B-A}) leads to the cumulative instream load. At the end of the study reach, the cumulative instream load is the best estimate of the total load added to the stream but is likely a minimum estimate because it only measures the net loading

for segments and does not account for loss resulting from reaction.

For those segments that include a sampled inflow, a third load calculation is possible. If stream sites A and B surround an inflow sample, location I:

$$\Delta M_I = C_I(Q_B - Q_A)(0.0864) \qquad (4)$$

where:

ΔM_I is the load attributed to the inflow, I, in kg/day,

C_I is the inflow concentration, in mg/L,

Q_B is the discharge at site B, in L/s, and

Q_A and 0.0864 are defined in equation 2.

Summing the inflow loads along the study reach produces a longitudinal profile of the cumulative inflow load. This sum can be compared to the cumulative instream load to indicate how well the sampled inflows account for the load measured in the stream. The cumulative instream and cumulative inflow profiles would be nearly equal if the sampled inflows were completely representative of the constituent concentration for all the water entering the stream, but that is rarely the case. Ground-water inflow into streams affected by mine drainage often has higher concentrations of metals than surface-water inflows into the same stream segment. This causes the cumulative instream load to be greater than the cumulative inflow load and can indicate important areas of unsampled inflow load, which is defined as:

$$\Delta M_U = \Delta M_{B-A} - \Delta M_I \qquad (5)$$

where:

ΔM_U is the unsampled inflow load, in kg/day, and

ΔM_{B-A} and ΔM_I are defined in equations 3 and 4.

Unsampled inflow can be calculated for individual stream segments even if the segment does not include a sampled inflow or for the entire study reach by comparing the cumulative instream and inflow loads. If the value is negative for the entire study reach, however, it can still be positive for some individual stream segments. Note that ΔM_{B-A} includes all sources of loading within a stream segment and, in most cases, does not distinguish the quantity added by an individual source.

Because there is measurement error inherent in discharge estimates, chemical analysis, and sampling, a load error equation is used to constrain the changes of sampled instream load. The load error is calculated from an equation that accounts for these potential sources of error (McKinnon, 2002):

$$\text{Load error} = (\sqrt{Q_A^2 \Delta C_A^2 + C_A^2 \Delta Q_A^2})(0.0864) \qquad (6)$$

where:

ΔC_A is the precision of chemical analysis,

ΔQ_A is the precision of discharge calculation, and

Q_A, C_A and 0.0864 are defined in equation 2.

The value of ΔC_A is calculated in a manner analogous to that used by Friedman and Erdman (1982) for single operator precision. The coefficient of variation (CV), representing precision, and the mean concentration are calculated for repeated analysis of a constituent in a set of standard reference samples spanning a range of concentrations. Values for CV are regressed as a power function of the mean concentrations to obtain an equation expressing analytical precision, ΔC_A, as a function of concentration:

$$\Delta C_A = a(C_A)^b \qquad (7)$$

where:

ΔC_A is precision for the chemical measurement at site A, in percent,

a is the coefficient from regression,

C_A is the concentration of the constituent at site A, and

b is the exponent from regression.

The value of ΔQ_A is based on the CV for the plateau tracer concentration at the transport sites during the period of synoptic sampling. For example, for the upper injection reach (fig. 3A), the mean bromide concentrations at transport sites T1 and T3 during synoptic sampling were 4.23 mg/L and 1.74 mg/L, respectively (site T2 was not located on the main channel, but on the returning ditch, an inflow). The value of CV for site T1 was 2.5 percent and for site T3 was 9.6 percent. Similar to the procedure for analytical precision, the values of CV for each mean are used to develop a linear regression for ΔQ_A:

$$\Delta Q_A = mC_A^T + b \qquad (8)$$

where:

ΔQ_A is the discharge error at site A,

m is the slope from linear regression,

C_A^T is the tracer concentration at site A, and

b is the intercept from linear regression.

Both ΔC_A and ΔQ_A give the percentage of C_A and Q_A to be substituted into equation 6 to calculate load error. The load error is compared to the change in load to the next site, ΔM_{B-A}. If the absolute value of ΔM_{B-A} is greater than the load error, then there has been a measurable and significant change
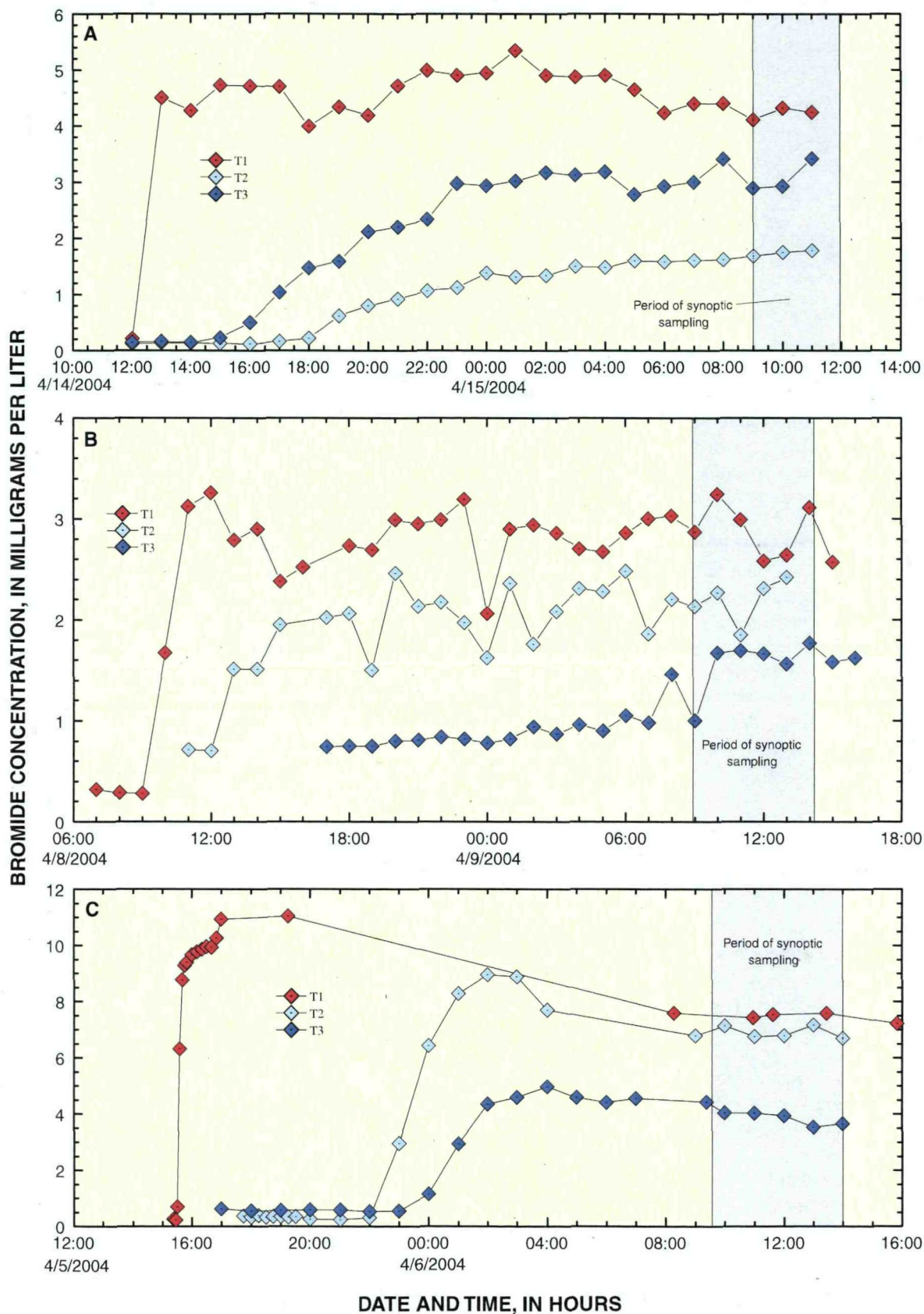
Figure 3.   Variation of bromide concentration at transport sites with time for (A) upper, (B) middle, and (C) lower injection reaches, Silver Creek, Utah, April 2004.

in load. Only the values of ΔM_{B-A} that are greater than the load error are included in the longitudinal profiles of sampled instream load and the cumulative instream load.

Sample Classification

An important objective of synoptic sampling is to recognize patterns or chemical characteristics among samples that can indicate the sources of mine drainage. Water that interacts with distinct mineral assemblages may exhibit characteristic chemical signatures that can provide distinctions among the inflow samples. Thus, groups of inflow samples are identified by their similarities. In this study, distinctions among inflow groups lead to understanding differences in drainage from the various areas where tailings occur. Groups of stream-water samples indicate where major changes occur in surface-water chemistry. Sample classification was done separately for inflow and for stream-water samples.

A cluster analysis method called partitioning around medoids was used to evaluate distinctions among the inflow and stream-water samples (Kaufman and Rousseeuw, 1990). For both stream-water and inflow samples, the method uses the Euclidian distance between samples in multi-dimensional space to determine clusters or groups of samples with samples that are similar, and yet groups that are the most distinguished from each other. To emphasize the linear relations among variables, the chemical concentration of each constituent, is expressed in millimoles per liter. These values are converted to standardized variables in the analysis. Only filtered concentrations were used as input to the analysis.

Discharge from Tracer Dilution

Understanding the effects of flood-plain tailings on mass loading to Silver Creek is based on three critical lines of evidence. First is the estimation of discharge from the tracer dilution, second is the pattern of chemical variation of inflow and instream concentrations, and third is the longitudinal pattern of mass loading that comes from a combination of the synoptic discharge and chemical data.

To estimate discharge from tracer dilution, a concentrated sodium bromide solution was slowly pumped into the stream at the upstream end of each injection reach. Details of the time, injection rate, and tracer concentration of the injectate solution for each injection reach are presented in table 1. During the periods of synoptic sampling, the tracer concentration in the middle (fig. 3B) and lower (fig. 3C) reaches appeared to attain a steady-state plateau at each transport site. During synoptic sampling for the upper injection reach (fig. 3A), however, a plateau occurred at site T1, but tracer concentrations at sites T2 and T3 appeared to be increasing. Thus, discharge estimates downstream from 525 m for the upper injection reach were not calculated. For the middle and lower injection reaches, however, where

concentrations vary with downstream distance, but not with time, values of bromide concentration for each synoptic stream site can be used to estimate a discharge value by using equation 1. Smoothed bromide concentrations, using the method of Velleman and Hoagland (1981), were used in the discharge calculations, and the smoothed concentrations of the bromide tracer and estimated discharge at all of the stream sites are listed in table 2 (located at back of report).

Bromide concentrations of inflow samples were variable (fig. 4B). The median bromide concentration among inflows (excluding those inflows that directly drained roads) was 0.3 mg/L (fig. 4B), which is a likely background concentration for this study reach. Twelve samples had a bromide concentration of greater than 0.5 mg/L (fig. 4B), and those samples most likely had some portion of stream water in them. Most of these samples were collected in the middle injection reach where the diversion of water could have caused some back mixing with inflows. Because higher bromide concentrations among inflow samples were likely the result of injected bromide, and not the result of natural sources of bromide, the instream bromide concentrations should remain acceptable for calculating discharge with equation 1.

Discharge estimates must be viewed in the context of variation that occurred during the 10-day period of the injections (fig. 4A). Hourly-scale variation in the gaging-station record resulted from variable discharge of the WWTP, and this variation did not occur upstream from the WWTP. Daily scale variation was a result of diel variations from snowmelt. Two periods of rain occurred and discharge peaked at the gaging station at about 0:00 hours on April 8 and 0:00 hours on April 9. The period of synoptic sampling for each injection is indicated by vertical lines, and discharge at the gage varied from an average of 110 L/s during the lower injection, to 209 L/s during the middle injection, to 67 L/s during the upper injection.

Discharge at the end of the middle injection reach (fig. 4B), was substantially greater than at the beginning of the lower injection reach. In a temporal context (fig. 4A), the difference is explained by the storms that occurred between the two injections. The base discharge at the gaging station was 123 L/s higher during the middle than during the lower injection and mostly accounts for the difference of 142 L/s (fig. 4A) between the two injection reaches. The comparable values of discharge at the end of the upper injection reach on April 14 and the beginning of the middle reach on April 9 should differ by much more than they do, because discharge at the end of the upper injection reach on April 9 should have been greater after the storms. Not all the discharge from the upper injection reach, however, was diverted to the natural channel for the middle injection reach, and the amount that was diverted was nearly equal to the discharge at the beginning of the middle injection reach on April 9. Thus, the temporal variations over the 10-day period can explain the discharges illustrated in figure 4B.
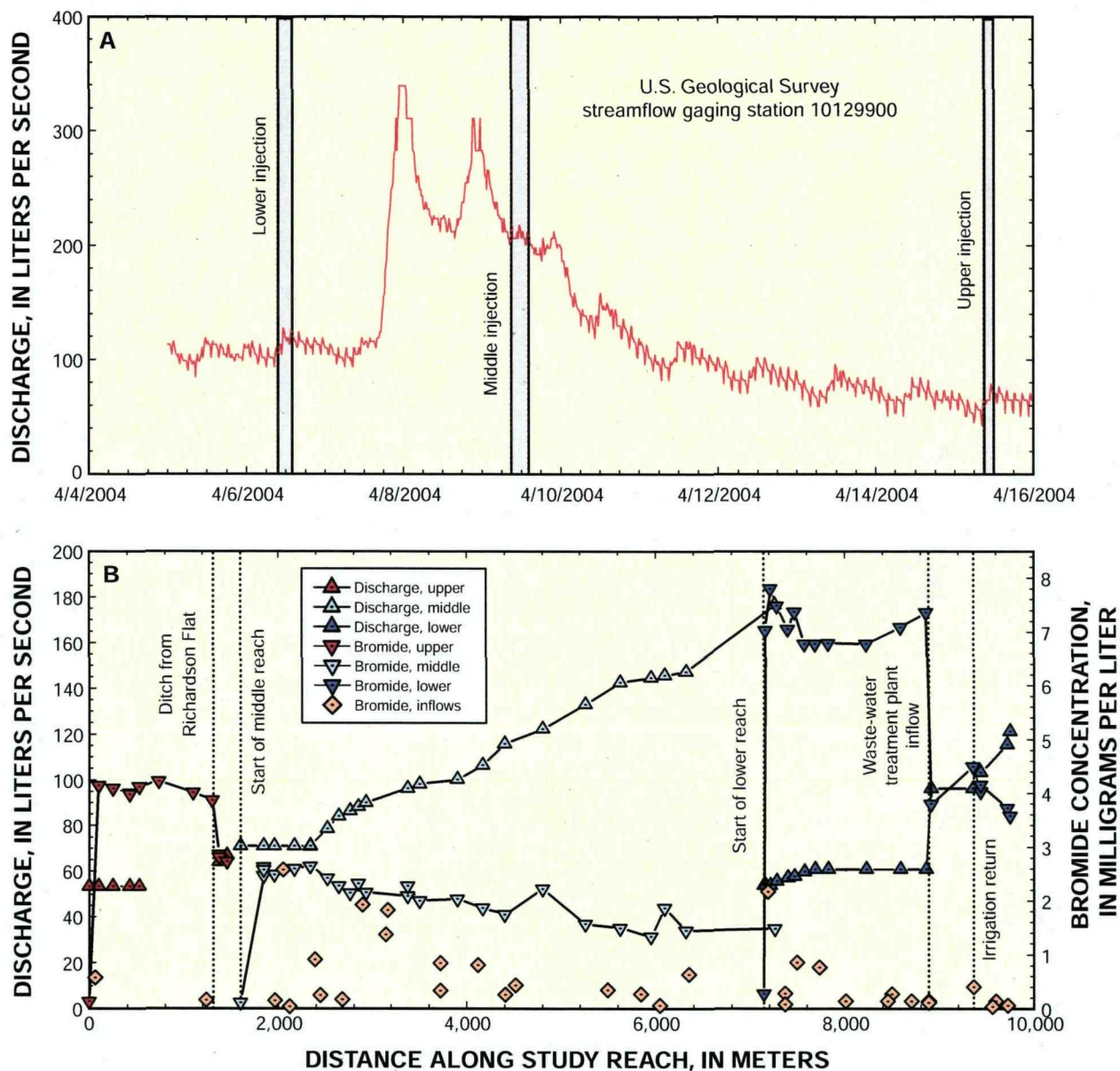
Figure 4.   Variation of (A) discharge measured at U.S. Geological Survey streamflow-gaging station 10129900 with time and (B) estimated discharge and bromide concentration with distance for stream and inflow samples along the study reach, Silver Creek, Utah, April 2004.

Chemical Variation of Synoptic Samples

The discharge profiles of each injection reach are combined with an equally detailed profile of stream and inflow chemistry. For this 10,000-m study reach, 52 stream and 46 inflow sites were sampled to provide the desired characterization (table 2). Results of chemical determinations are listed in table 3 for major ions and table 4 for trace elements (both tables located at back of report). All samples were evaluated for charge balance and all but two samples had a balance less than 5.2 percent; the median balance was 1.97 percent.

New spectroscopic technology, inductively coupled argon plasma/mass spectrometry, (ICP-MS), makes the determination of low concentrations of metals possible. Method detection limits for the analyses of the synoptic samples are listed in table 5; many detection limits were less than one part per billion. Precision for each element was determined by a modification of the method for single operator precision (Friedman and Erdmann, 1982). Statistics for calculating single operator precision were developed by running certified standards and field standard reference samples at regular intervals throughout the chemical analysis. By calculating the CV for a given concentration from these reference standards, power function equations for CV as a function of concentration were developed; coefficients and exponents for these equations are listed in table 5, and, as described in the "Methods" section, are used in the load error calculation to determine the ΔC_A term in equation 6.

Inflow Samples

Metal concentrations measured for inflow samples span nine orders of magnitude, and a comparison using box plots (Velleman and Hoaglin, 1981) demonstrates this range (fig. 5). Such a large range of concentration suggests that the inflows sampled in this study most likely represent the possible range of inflow chemistry affecting Silver Creek in the study reach. A substantial percentage of the samples had cadmium, iron, manganese, strontium, and zinc concentrations that were greater than 100 µg/L. Zinc concentration in samples from 4 inflows exceeded 100,000 µg/L, and one of these exceeded 1,000,000 µg/L (fig. 5; table 4). These high concentrations indicate the potential importance of these flood-plain tailings as sources of metals to Silver Creek.

Inflow samples have been classified using cluster analysis into four groups on the basis of their chemical composition. Distinctions among the groups are evident from variations in pH and concentrations of selected constituents (table 6). The groups have been arranged in an order of decreasing pH and increasing concentration (with the exception of alkalinity), and this order could represent the extent of weathering of flood-plain tailings or weathering of tailings having variable content of sphalerite and other metal-rich minerals such as rhodochrosite. None of the inflow samples can be considered totally unaffected by interaction with tailings material, but the groups may represent the extent of interaction or else the effect of differing mineralogy in the tailings material. Inflow samples that have the highest values of pH (least and moderately affected groups) also have the lowest concentrations of calcium, sulfate, and zinc, but the highest concentration of alkalinity. On the other hand, samples with the lowest pH have the highest concentrations of calcium, sulfate, and zinc (substantially affected and most affected groups).

Spatially, general distinctions exist among the groups of inflow samples. Inflows most affected by tailings occurred at the

Table 5. Method detection limits and relative standard deviation of quality-assurance samples, Silver Creek, Utah, April 2004.

[MDL, method detection limit]

Constituent	MDL, in micrograms per liter	Coefficient of variation	
		Coefficient	Exponent
Calcium	416	7.7586	-.2861
Magnesium	101	2.4179	-.3756
Sodium	302	3.7271	-.2209
Potassium	36	2.2376	.1502
Alkalinity as CaCO$_3$	500		
Sulfate	1,760	6.6228	-.3185
Chloride	480	3.7271	-.2209
Bromide	80	5.7087	-.3406
Silica, as Si	309	3.0626	.0624
Aluminum	.2	1.6461	-.4146
Arsenic	.01	3.6077	-.176
Barium	.1	1.2463	-.1304
Cadmium	.09	.6576	-.3452
Cobalt	.01	.1594	-.57
Chromium	.05	.8397	-.305
Copper	.04	3.7668	.0892
Iron	.3	1.3058	-.2804
Lead	.01	.7153	-.1152
Lithium	.5	1.0295	-.3813
Manganese	5	1.249	-.0496
Molybdenum	.04	.8158	-.2531
Nickel	.37	1.3722	-.4094
Silver	.01	3.2254	-.2851
Strontium	2	11.556	.0854
Uranium	.003	1.0411	-.0962
Vanadium	.01	.08742	-.2047
Zinc	22	.8362	-.7002

Figure 5.   Box plots showing the range of trace-element concentration among synoptic inflow samples collected from Silver Creek, Utah, April 2004.

Table 6. Median, minimum, and maximum pH value and concentration of selected consituents in groups of inflow samples collected along Silver Creek, Utah, April 2004. Groups are labeled by the degree to which they are affected by interaction with mining wastes.

[mg/L, milligrams per liter; LD, less than detection limit; µg/L, micrograms per liter]

Constituent	Group	Number of samples	Median	Minimum	Maximum
pH, in standard units	Least	3	7.92	7.64	8.16
	Moderate	28	7.79	6.94	8.24
	Substantial	12	7.37	5.98	7.57
	Most	2	3.75	3.36	4.13
Calcium, in mg/L	Least	3	67.4	44.1	107
	Moderate	28	220	52.9	463
	Substantial	12	388	271	537
	Most	2	458	436	479
Alkalinity as CaCO$_3$, in mg/L	Least	3	161	125	230
	Moderate	28	150	33.6	279
	Substantial	12	103	24.9	177
	Most	2	LD	LD	LD
Sulfate, in mg/L	Least	3	51.5	9.4	107
	Moderate	28	343	29.0	761
	Substantial	12	1,083	667	3,250
	Most	2	3,595	3,510	3,680
Zinc, in µg/L	Least	3	178	25.6	657
	Moderate	28	3,380	12.8	25,500
	Substantial	12	37,443	8,380	1,070,000
	Most	2	200,838	132,000	270,000

beginning and near the end of the middle injection reach (fig. 6, orange triangles at 1,965 m and 5,928 m). Both these inflows originated directly from tailings piles (table 2). Moderately affected inflows (light blue triangles) mostly occurred from the beginning of the study reach (0 m) to near 4,403 m. Substantially affected inflows (yellow triangles) mostly occurred from 5,251 m to 8,497 m. In general, this group of substantially affected inflows not only had lower pH than the least and moderately affected groups, but also had higher concentrations of sulfate and zinc (fig. 7A and B).

If the mining wastes were derived from ore deposits that had the same age of mineralization, the sphalerite might have a uniform ratio of cadmium to zinc. In a plot of cadmium with zinc, a constant ratio is represented by a line of unit slope (fig. 8A). Not all samples plot along a line of unit slope (fig. 8A). Samples from the least and the moderately affected inflows had the most variable cadmium to zinc ratio, and samples from the substantially and most-affected inflows had a relatively constant ratio. This corresponds to a spatial pattern of higher ratios occurring among inflow samples between 2,000 and 4,800 m (fig. 8B), or the area of the upper meadow tailings piles (fig. 1). Stream-water samples from this same area and also downstream to the end of the study reach generally had the same ratio and plot along the line of unit slope (fig. 8A). This result indicates that zinc and cadmium in the middle and lower injection reaches were mostly obtained from the tailings

piles in those areas rather than from upstream sources. This is consistent with the substantial increases in zinc concentration among samples collected downstream from 2,000 m (fig. 7B) and has implications for remediation.

Stream Samples

Distinctions that occur among groups of stream-water samples have a different implication than distinctions among groups of inflow samples. As noted, distinctions among inflow sample groups could result from the degree of interaction with flood-plain tailings or the variable chemical character of tailings, both possibilities reflecting catchment sources of zinc. Distinctions among stream-water groups along the study reach in Silver Creek, however, represent changes in stream-water chemistry in response to inflows from the various sources. Consequently, the resulting classification of stream-water samples into groups represents a sequence of changes along the study reach. The locations of different groups are indicated in figure 1.

Sulfate and zinc concentrations illustrate the pattern of change for stream-water samples collected along the study reach (diamond symbols for stream-water samples; fig. 7A and B). From upstream to downstream, five groups were distinguished by cluster analysis and are designated as A-E.

- Group A (dark blue diamonds; 0 to 1,843 m) – Sulfate concentration at the beginning of the study reach was consistently near a median concentration of 294 mg/L. Zinc concentration progressively increased along the upper injection reach from 1,300 to almost 1,700 µg/L at 1,452 m. The increase could indicate a contribution from the "upstream" tailings (fig. 1), but the median zinc concentration of 1,590 µg/L was relatively low compared to concentrations downstream.

- Group B (light blue diamonds; 861 m to 1,309 m) – The chemical character of samples from the right branch of the upper injection reach (stream-water samples collected at 861 m, 1,229 m, and 1,309 m) differed from that of the main channel, with a slightly higher sulfate concentration, but a lower zinc concentration. The difference in chemistry indicates that ground water may flow into the right branch after the stream splits, but it is of note that metal concentrations are lower as a result.
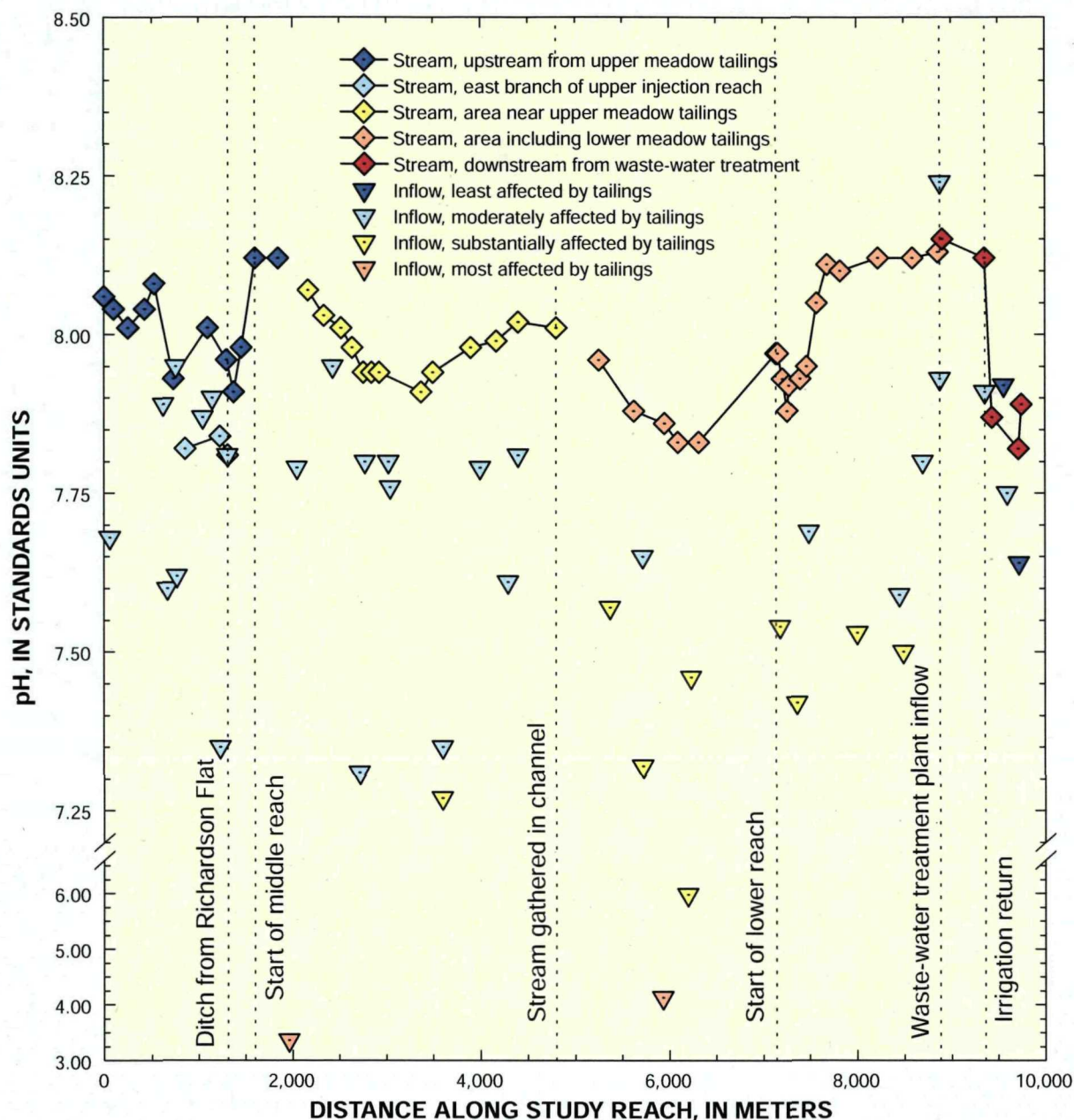
Figure 6. Variation of pH with distance along the study reach for stream-water and inflow samples collected along Silver Creek, Utah, April 2004.

- Group C (yellow diamonds; 2,171 m to 4,800 m) – Downstream from the point where water was diverted to the middle injection reach at 1,452 m, the first two stream-water samples (1,601 m and 1,843 m) were similar to the upstream stream-water samples (group A). However, there was a distinct change at 2,171 m that reflects the influence of the upper meadow tailings piles (fig. 1). Inflows from the upper meadow tailings piles caused substantial increases in both sulfate and zinc concentrations. Median concentrations between 2,174 m and 4,800 m increased to 332 mg/L sulfate and 3,730 µg/L zinc (fig. 7A and B).

- Group D (orange diamonds; 5,251 m to 8,862 m) – Concentrations of sulfate and zinc increased substantially a second time from the influence of the lower meadow tailings piles (fig. 7). Increases in both sulfate and zinc concentration occurred at the end of the middle injection reach, and again at the start of the lower injection reach. Particularly for zinc concentration, the increases were substantial and reflect the effect of the tailings, both in the lower meadow area (about 5,000 m to 7,142 m) and the Old Big 4 mill area (7,142 m to 8,909 m). The mole ratio of the stream water for cadmium to zinc varies as a result of inflows in both these locations; first a decrease
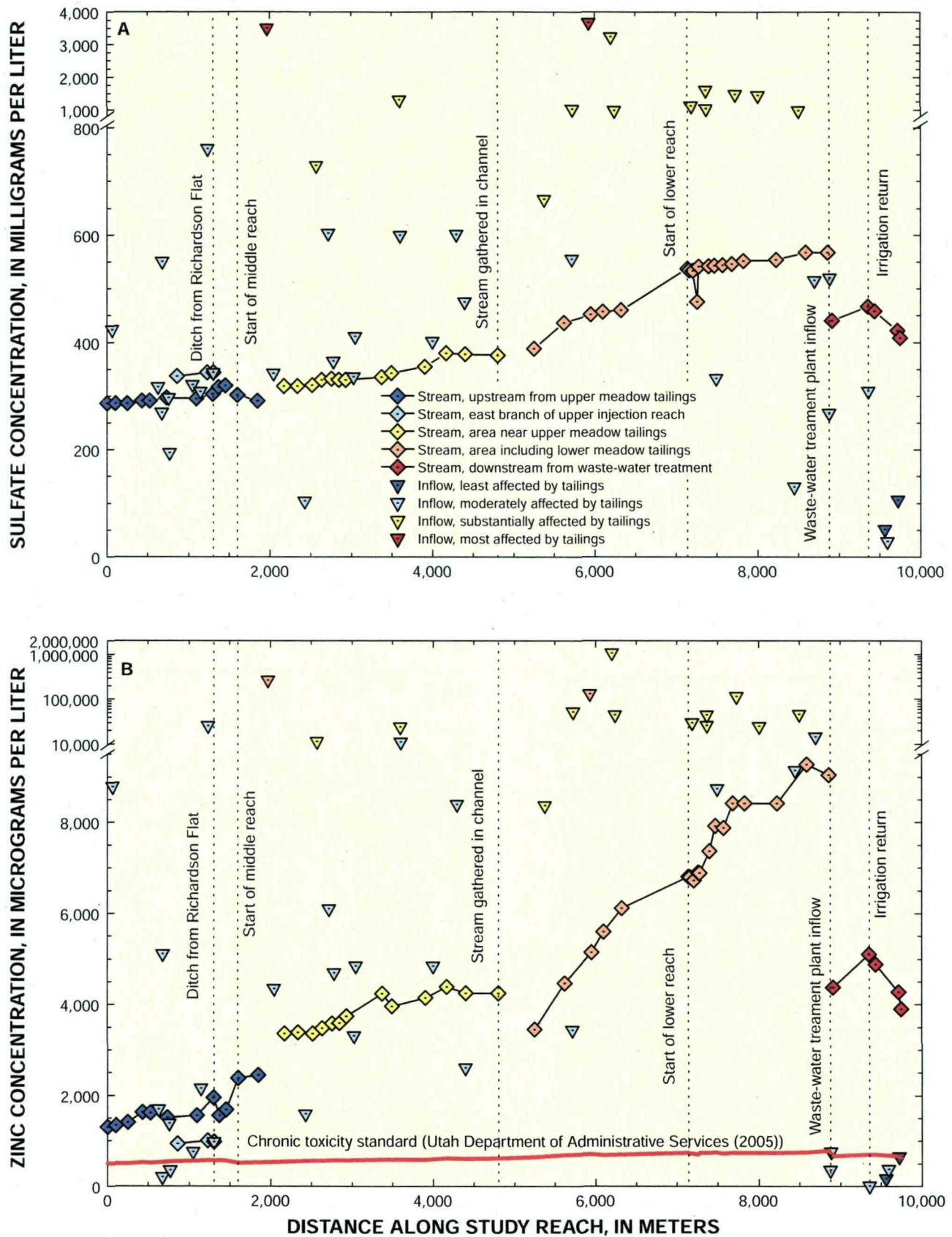
Figure 7.   Variation of (A) sulfate and (B) zinc concentrations with distance along the study reach for stream-water and inflow samples collected along Silver Creek Utah, April 2004.
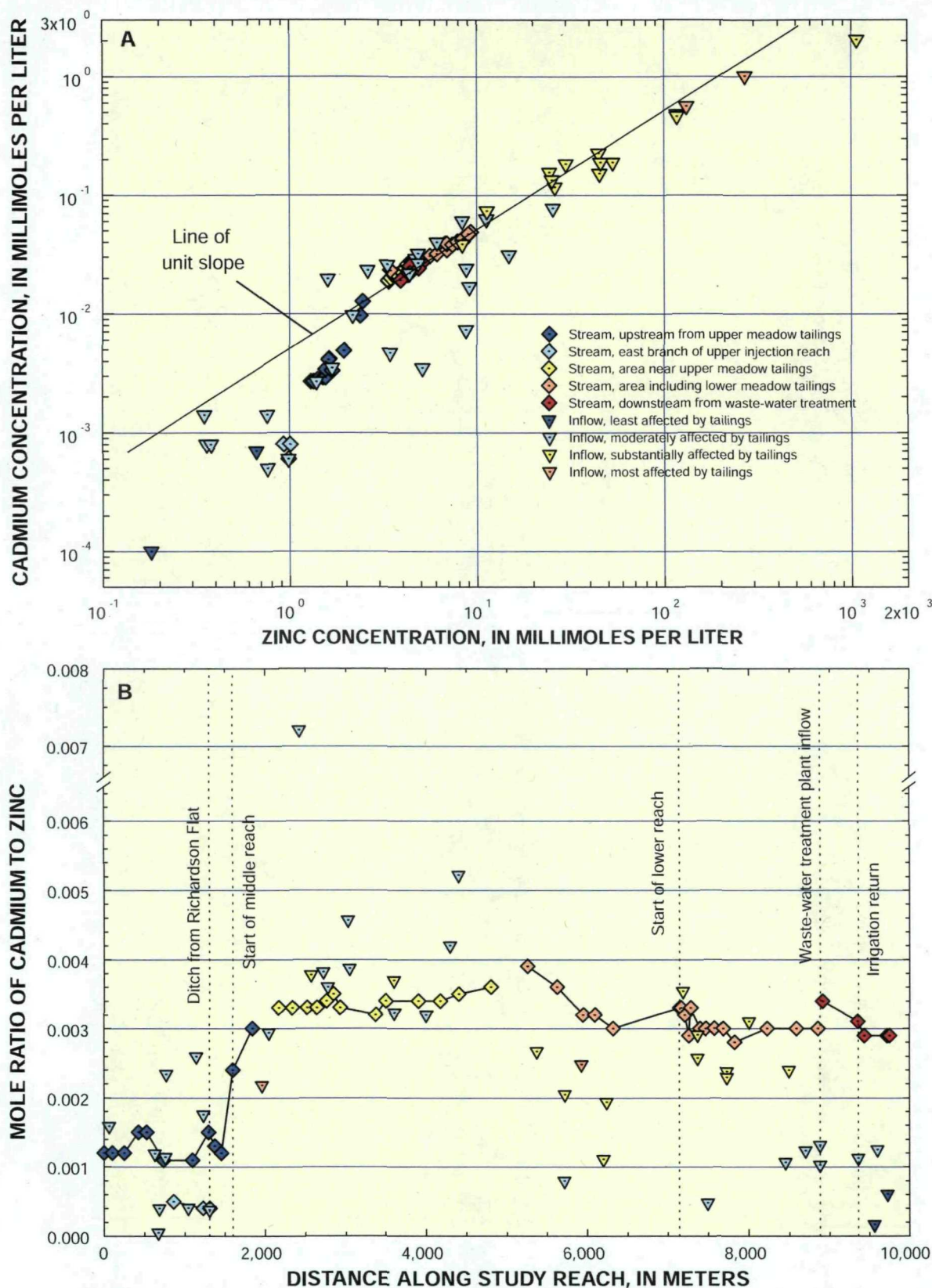
Figure 8. Variation of (A) cadmium with zinc concentration and (B) mole ratio of cadmium to zinc with distance along the study reach for stream-water and inflow samples collected along Silver Creek, Utah, April 2004.

occurred in the ratio from 5,251 m through 6,322 m, and then a steady ratio occurred near 7,571 m (fig. 8).

- Group E (red diamonds; 8,909 m to 9,747 m)
  – Compared to the upstream group, almost all concentrations were lower as a result of dilution by the inflow of the WWTP (fig. 7), which entered Silver Creek at 8,881 m. Further dilution occurred downstream from the irrigation return flow at 9,360 m.

As described, the mole ratio of cadmium to zinc in stream-water samples indicates the influence of inflows from the tailings piles in the upper and the lower meadow areas (fig. 8B). Waters from group A (dark blue diamonds) had a ratio near 0.0012, but at 2,171 m, the ratio increased to a nearly constant value of 0.0033 in response to high ratios of inflow waters. At 5,251 m, the instream ratio began to decrease in response to lower ratios of inflows from the lower meadow tailings piles, as noted above. In the lower injection reach, downstream from 7,142 m, the instream cadmium to zinc ratios in the stream-water samples were nearly constant. The initial change at 2,171 m and the subsequently constant ratio suggest the effect of tailings piles in the upper meadow area as a source of these metals.

Concentrations of cadmium and zinc in stream-water of Silver Creek exceeded chronic aquatic-life standards (Utah Department of Administrative Services, 2005). All the stream-water samples exceeded the hardness-based chronic toxicity level for zinc (fig. 7B). For cadmium, water samples collected from all stream sites downstream from 1,601 m exceeded the hardness-based chronic toxicity standard. All instream concentrations of copper, lead, and nickel were less than the calculated hardness-based chronic toxicity standards.

Ten locations from the lower injection reach included analysis of both the filtered and unfiltered samples (table 4). In all but the replicate sample at 9,438 m, aluminum, arsenic, copper, iron, lead, and silver were substantially in the colloidal phase. Cadmium and zinc were partly colloidal in some of the samples, but the remaining metals were mostly in the filtered phase. These metals commonly form or are sorbed to colloids in streams affected by mine drainage (Kimball and others, 1995; Nordstrom and Alpers, 1999; Smith, 1999), particularly in the pH range of these Silver Creek samples. The presence of these metals in the colloidal phase suggests they may present a chronic toxicity problem in addition to the acute toxicity.

Principal Locations of Mass Loading

Detailed longitudinal profiles of loading along the study reach come from the combination of the spatially detailed discharge and chemical data and indicate where the most substantial loads enter the stream. Although the three separate injection reaches were studied on different days and under different flow regimes, the combination of results from all three can be unified to present a profile for the entire

stream. This combination was accomplished by calculating significant changes (using equation 5) for each stream segment within each injection reach. These significant changes were then summed incrementally along each injection reach. The resulting load at the end of the upper injection reach was then used as the starting load for the middle injection reach. Likewise, the sum of changes at the end of the middle injection reach was used as the starting load for the lower injection reach.

This calculation leads to a detailed longitudinal profile of mass loading for each element that represents sums of significant changes along the entire study reach. Note that the profile calculated in this manner does not represent the absolute load. For almost all the constituents, the profile can be summarized with reference to five principal locations, summarized in table 7, that account for most of the mass loading along the study reach. Three of the locations consist of only one stream segment (1, 4, and 5), while two locations are sums of the load contributions from several stream segments (2 and 3). Photographs of some of the principal locations are shown in figure 2. Mass loading at these five principal locations is illustrated with the load profiles of sulfate, aluminum, and zinc (figs. 9, 10, and 11, respectively).

Upstream from the Study Reach

The first stream segment, represented by the load at 0 m, indicates the net loading from all upstream sources (fig. 2A). Metal loading has been documented at several locations upstream from the study reach (Kimball and others, 2004). These upstream sources contribute more than 10 percent of the cumulative instream loads of calcium, magnesium, sodium, potassium, sulfate, chloride, aluminum, barium, chromium, and strontium. For example, sulfate load (fig. 9A) at the upstream end of the study reach was greater than 1,300 kg/day; this segment contributed the second largest load of any individual stream segment for sulfate (fig. 9B).

Upper Meadow Tailings Piles

Six stream segments, from 2,171 m to 2,757 m (fig. 2B) represent the next principal location of mass loading. This stream reach is notable for the increase in loads of several metals, including aluminum (41 percent of total load), barium (31 percent), cadmium (23 percent), copper (23 percent), iron (33 percent), lead (19 percent), nickel (29 percent), and strontium (19 percent). This stream reach had the greatest loading for aluminum (fig. 10B), but the loadings of sulfate (fig. 9B) and zinc (fig. 11B) were relatively small in this stream reach. The sampled inflow load of aluminum for this area was about twice the sampled instream load (fig. 10A). This result indicates that either the sampled inflow concentrations at the three inflows upstream from 2,171 m were higher than the concentration of aluminum that actually affected the stream load, or else there was substantial

Table 7. Summary of principal locations of mass loading for Silver Creek, Utah, April 2004.

[<, less than]

Constituent	Area						Total
	1	**2**	**3**	**4**	**5**	**Others**	
	Loading upstream from the study reach	Upper meadow tailings piles	Lower meadow tailings piles	Upstream from Pivotal Promontory access road	Downstream from waste-water treatment plant; Big 4 tailings	Sum of all other segments	Sum of all segments
	Stream reach, in meters						
	0, start of study reach	2,171-2,337 2,337-2,519 2,519-2,637 2,637-2,757	4,403-4,800 4,800-5,251 5,251-5,624 5,624-5,950 5,950-6,093 6,093-6,322	6,332-7,142	8,862-8,909		
	Load, in kilograms per day						
Calcium	725	236	980	559	480	1,098	4,078
Magnesium	184	53.6	222	121	88.3	249	919
Sodium	705	158	265	289	540	537	2,494
Potassium	14.1	2.31	15.4	14.9	31.1	35.4	113
Sulfate	1,320	443	1,877	1,400	683	2,019	7,743
Chloride	1,630	328	1,000	967	1,190	1,063	6,179
Silicon	16.2	9.29	22.3	27.6	28.8	72.6	177
Aluminum	.067	.213	.115	.048	.032	.043	.518
Arsenic	.010	.002	.063	.008	.018	.053	.154
Barium	.304	.505	.061	.168	.134	.449	1.62
Cadmium	.012	.145	.138	.122	<.001	.206	.623
Chromium	.002	.001	.011	.000	.001	.002	.017
Copper	.009	.052	.079	.028	.008	.052	.228
Iron	.061	.749	.713	.281	.042	.431	2.28
Lead	.007	.031	.030	.024	<.001	.071	.163
Manganese	1.41	.813	5.31	3.32	<.001	5.14	16.0
Molybdenum	.007	.009	.008	.006	.048	.017	.095
Nickel	.012	.038	.027	.030	<.001	.023	.130
Strontium	3.53	4.24	3.70	3.41	1.78	5.70	22.4
Zinc	5.98	9.90	40.5	27.5	<.001	41.0	125

precipitation of aluminum from the stream before the samples were collected at 2,171 m. The kinetics of aluminum precipitation as hydroxide phases are rapid, and at the relatively high pH of Silver Creek, rapid precipitation is likely (Broshears and others, 1996; Lydersen and others, 1991).

Lower Meadow Tailings Piles

Six stream segments, from 4,403 m to 6,322 m, represent the lower meadow mass loading (fig. 2C and D). This area was important for loading of several constituents, including calcium, magnesium, sulfate, aluminum, arsenic, chromium, copper, iron, nickel, and zinc. Zinc loading was particularly important, and the sum of the six stream-segment contributions resulted in the largest contribution of zinc along the entire study reach (fig. 11B).

Upstream from Pivotal Promontory Access Road

A single segment, from 6,332 m to 7,120 m, accounts for a substantial amount of the total mass loading (fig. 2C). This single segment contributed more than 10 percent of the total load for every constituent except aluminum, arsenic, and chromium. The pond upstream from the access road (fig. 2C) area may be a result of ground-water discharge to the stream and merits further study.

Waste-Water Treatment Plant and Old Big 4 Mill Tailings

Another single segment, from 8,862 m to 8,909 m, is the last principal location of mass loading to the stream (fig. 2D). The single segment that receives discharge from the WWTP also receives inflow from the right bank that drains tailings. This location differs from the other four principal locations of loading because it essentially contributed no cadmium, manganese, lead, nickel, or zinc load (table 7). Individual discharge measurements were not made on these two inflows, but chemical mass balance indicates that the metal loading that did occur came principally from the tailings while major ion loading came from the WWTP.

Other Sources

The sum of all other stream segments (table 7) indicates the importance of dispersed locations of mass loading. Contributions of metals from other areas of the study reach are substantial for calcium, magnesium, potassium, sulfate, silica, arsenic, cadmium, lead, and zinc. These dispersed metal loadings reflect the widespread occurrence of tailings along the study reach. Tailings are not just localized in the principal locations where loading occurred.

Comparison between 2002 and 2004

Comparison of the loads between the 2002 and 2004 studies can help evaluate whether loads from 2004 were high because of the storm and snowmelt runoff. Four sampling points were common between the two studies, and the relation of zinc loads for the two studies is shown in figure 12. Although zinc load in 2004 was initially smaller than zinc load in 2002 both upstream and downstream from Richardson Flat (fig. 12, bars A and B), the 2004 load upstream from the WWTP (bar C) was substantially greater than the load in 2002. Part of the difference is a result of the diversion of flow for this study at 1,492 m. This additional water in the channel could have released the zinc from the streambed or facilitated release of greater loads from the tailings piles. However, even though the 2004 loads are much greater, the pattern of loading that indicates the principal locations of loading is still valid.

Summary and Conclusions

Detailed mass-loading profiles provide information to facilitate science-based decisions about targets for remediation. The significance of any particular source must be evaluated in the context of its metal loading. The study done on the southern portion of lower Silver Creek in Summit County, Utah, by the U.S. Geological Survey in cooperation with the Utah Department of Environmental Quality, Division of Water Quality, has provided discharge and chemical data to develop mass-loading profiles to indicate the principal locations where historical mill tailings are sources of metal load to the stream. Discharge was estimated by using a bromide tracer injection in three separate injection reaches. Although storms occurred between the injections, causing changes in discharge, the discharge values obtained in the separate injections were adequate to combine for mass-loading profiles. Detailed synoptic sampling provided an indication of the types of inflows affecting Silver Creek and also the major changes in stream chemical character along the study reach. These changes corresponded to the principal locations of metal loading to the stream, including (1) the beginning of the study reach, where an accounting of loading from upstream sources was possible, (2) the upper meadow tailings piles, from ground-water discharge, (3) the lower meadow tailings piles, from ground-water discharge, (4) the stream segment upstream from the Pivotal Promontory access road (6,322 m – 7,142 m), and (5) the stream segment where WWTP and additional ground-water discharge from Old Big 4 tailings occurs (8,862 m – 8,909 m). With loading data these principal sources can be appropriately compared.
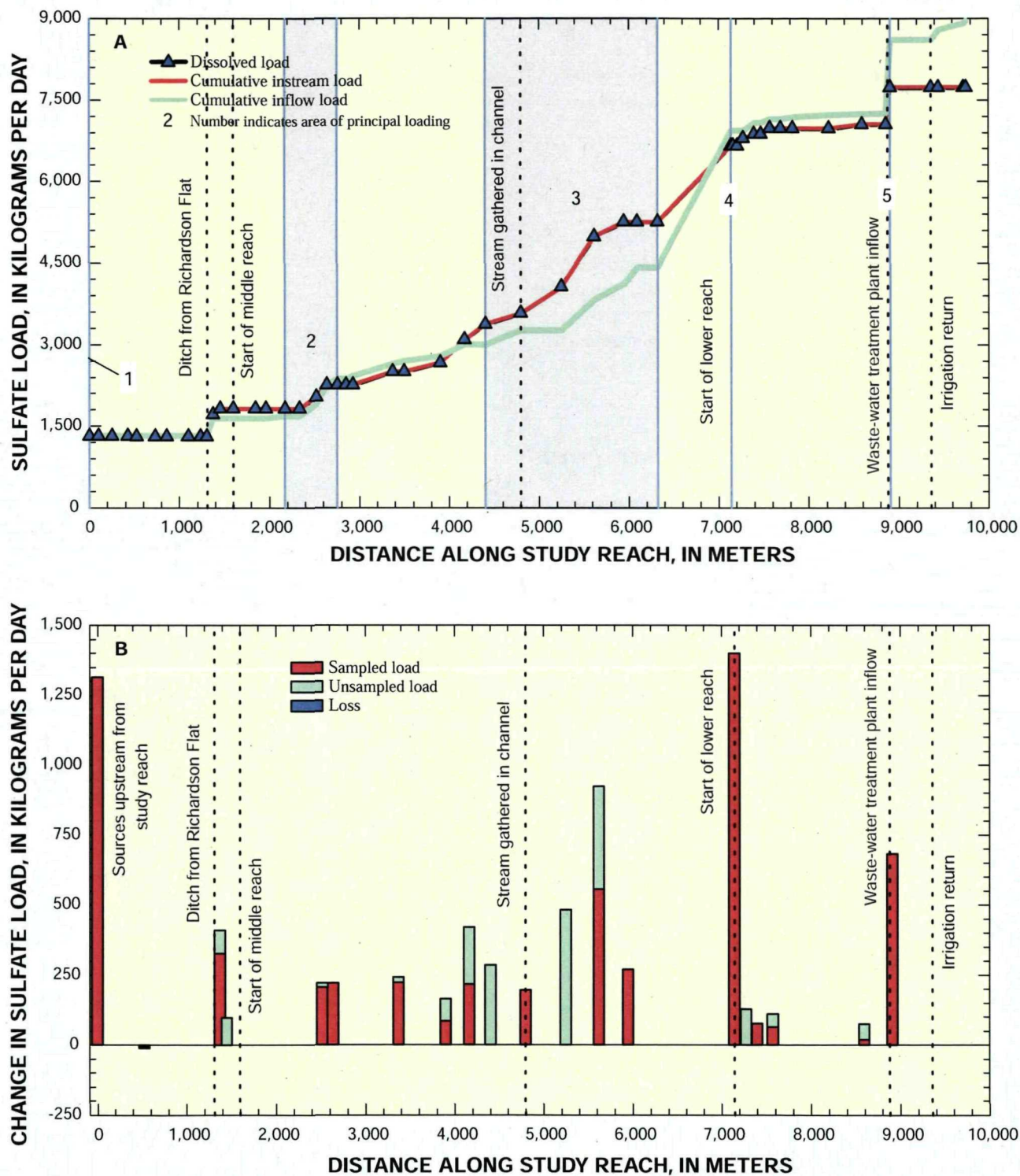
Figure 9.   (A) Variation of sulfate load with distance along the study reach and (B) change in sulfate load for individual stream segments, Silver Creek, Utah, April 2004.
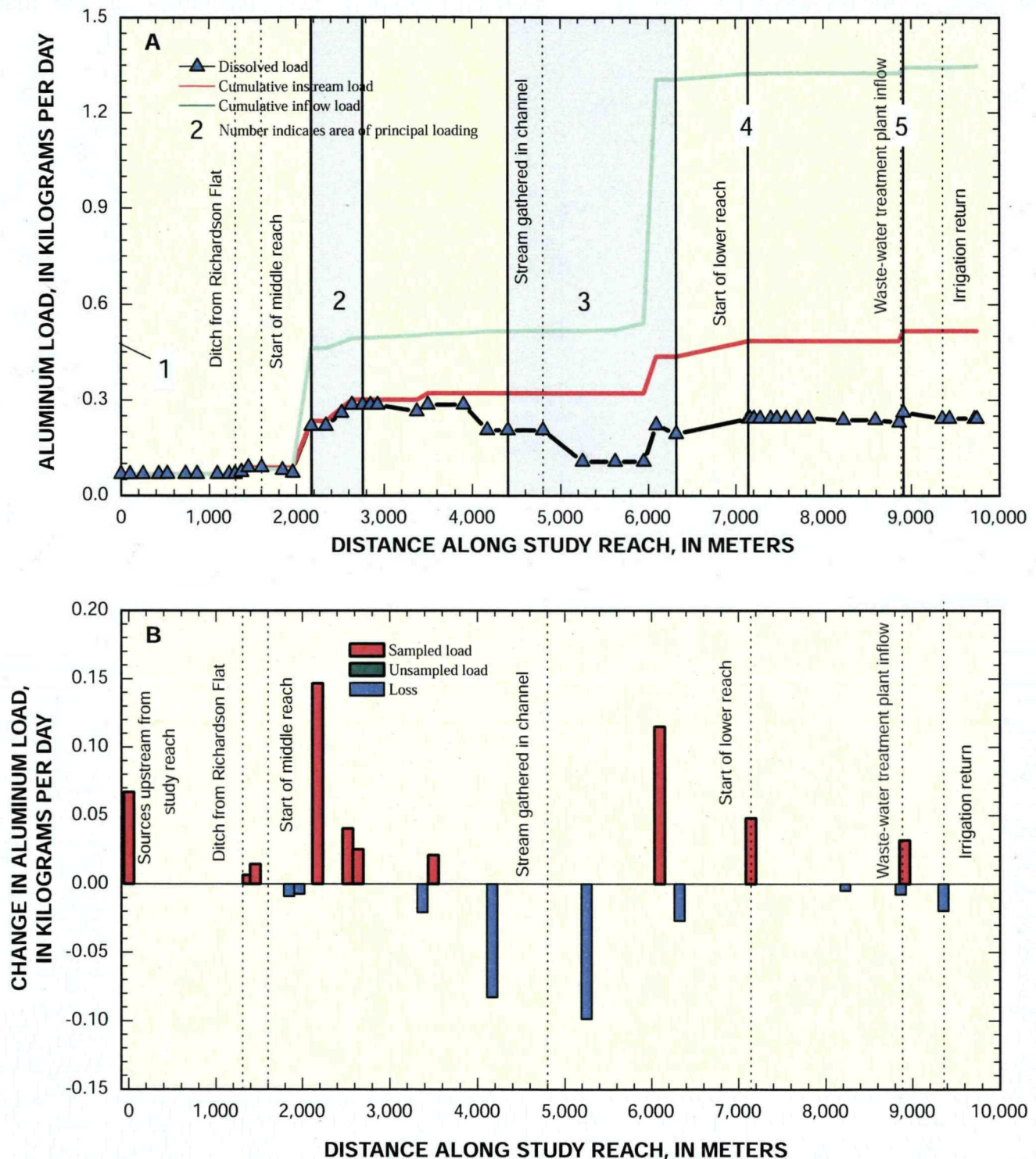
Figure 10. (A) Variation of aluminum load with distance along the study reach and (B) change in aluminum load for individual stream segments, Silver Creek, Utah, April 2004.
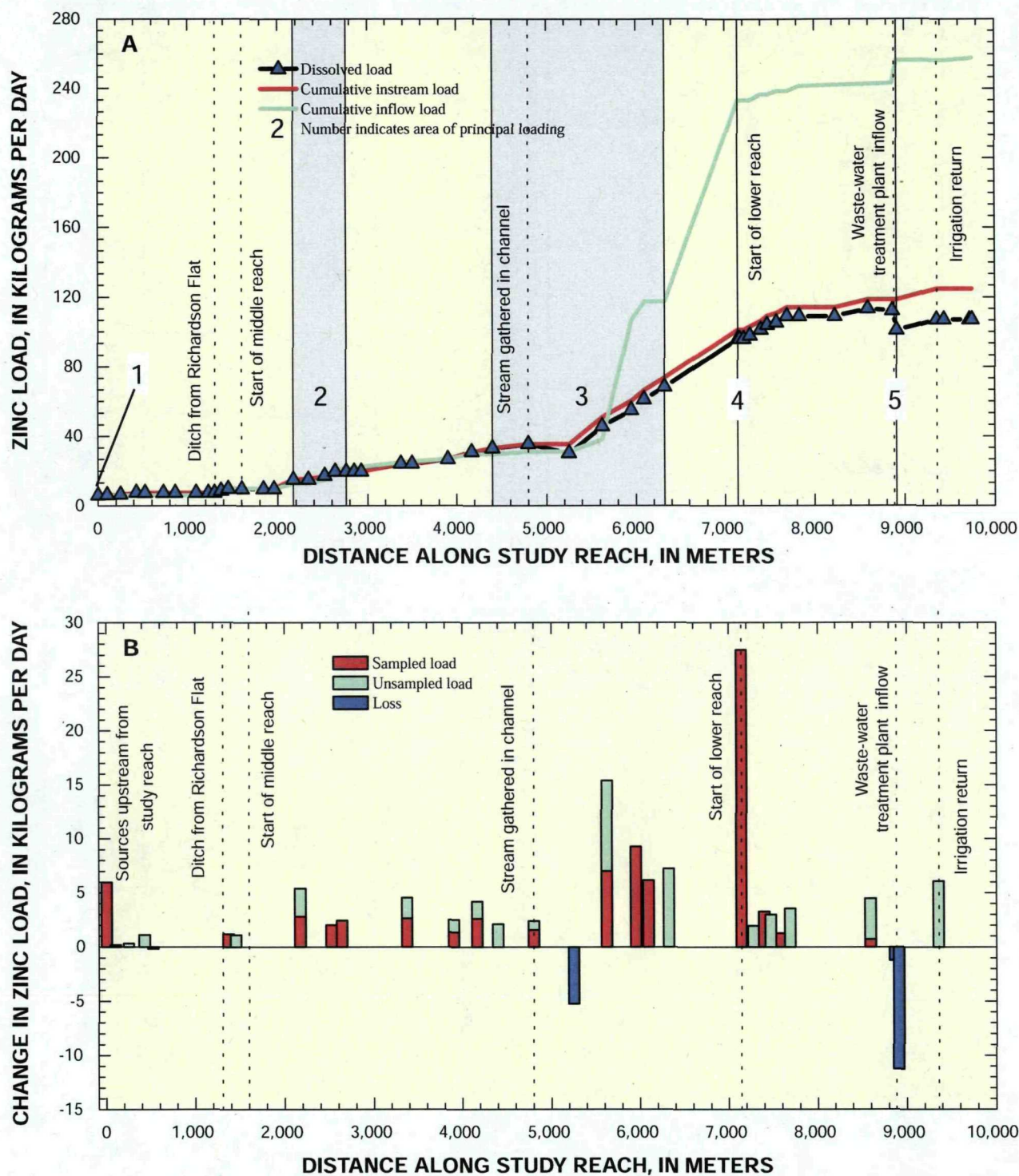
Figure 11.   (A) Variation of zinc load with distance along the study reach and (B) change in zinc load for individual stream segments, Silver Creek, Utah, April 2004.
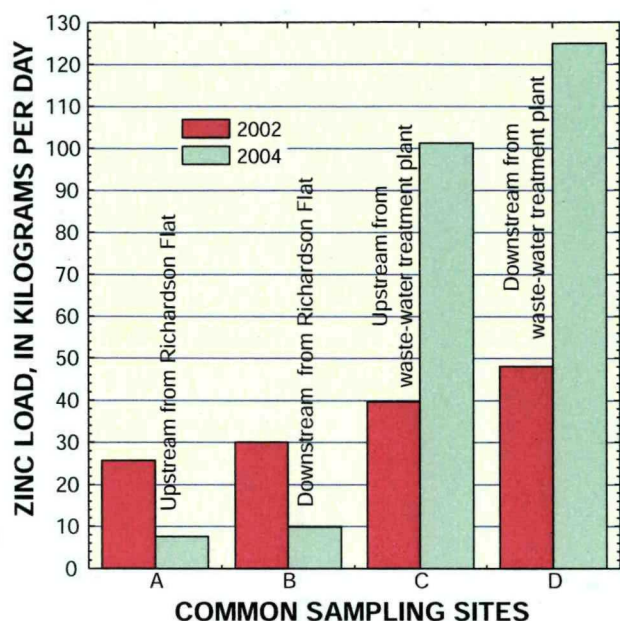
Figure 12. Zinc load at common sampling sites from studies in 2002 and 2004, Silver Creek, Utah.

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Table 2   25

Table 2. Bromide concentration of synoptic water samples and characteristics of the sites at which the samples were collected, Silver Creek, Utah, April 2004.

[Source: S, stream; LBI, left-bank inflow; RBI, right-bank inflow; Bromide: mg/L, milligrams per liter; Discharge: L/s, liters per second; NC, not calculated; NM, not measured; <, less than]

Sample identifi-cation	Distance, (meters)	Source	Description	Northing, (meters)	Easting, (meters)	Sample date and time	Bromide, (mg/L)	Dis-charge, (L/s)
			Upper injection reach					
SQ1-0000	0	S	T0 Upper - Injection site below U.S. Highway 40 bridge	4503080	461067	4/15/04 11:57	0.13	53.2
SQ1-0061	61	LBI	Discharge with iron staining from willows	4503135	461094	4/15/04 11:53	.58	NC
SQ1-0101	101	S	Upstream from "upstream tailings"	4503166	461120	4/15/04 11:46	4.14	53.2
SQ1-0250	250	S	Midway along the tailings in the left bank	4503278	461186	4/15/04 11:41	4.23	53.2
SQ1-0428A	428	S	T1 Upper - Upstream from Richardson Flat tailings influence	4503443	461292	4/15/04 11:35	4.11	53.2
SQ1-0428B	428	S	T1 Upper - Upstream from Richardson Flat tailings influence	4503443	461292	4/15/04 11:36	3.98	53.2
SQ1-0525	525	S	Upstream from pond area and bridge	4503456	461289	4/15/04 11:25	4.24	53.2
SQ1-0625	625	LBI	Pace-Homer ditch inflow; left of bridge	4503635	461337	4/15/04 11:20	3.25	NC
SQ1-0681	672	LBI	Small ditch upstream from highway	4503706	461323	4/15/04 11:03	1.79	NC
SQ1-0682	682	LBI	Black pipe spewing orange floc; source unknown	4503716	461326	4/15/04 10:58	1.28	NC
SQ1-0731	731	S	Downstream end of left, smaller culvert at highway	4503751	461331	4/15/04 13:16	4.22	NC
SQ1-0757	757	LBI	Ditch downstream from highway	4503764	461316	4/15/04 10:31	3.63	NC
SQ1-0770	770	LBI	Draining ditch on downstream side of highway	4503790	461331	4/15/04 10:01	< .03	NC
SQ1-0861	861	S	Right channel - downstream end of larger culvert at highway	4503690	461409	4/15/04 10:15	2.07	NC
SQ1-1050	1,050	RBI	Right channel - ditch from area of Richardson Flat	4503814	461499	4/15/04 10:08	.24	NC
SQ1-1095	1,095	S	Upstream end of culvert under rail trail	4503991	461348	4/15/04 9:55	4.01	NC
SQ1-1148	1,148	RBI	Right channel - second ditch from area of Richardson Flat?	4503896	461517	4/15/04 9:52	3.59	NC
SQ1-1229	1,229	S	Right channel - downstream from small pond in channel	4504001	461523	4/15/04 9:41	1.97	NC
SQ1-1235	1,235	RBI	Channel draining meadow area	4504147	461456	4/15/04 9:49	.16	NC
SQ1-1300	1,300	S	Upstream from return of irr ditch	4504211	461461	4/15/04 9:18	3.87	NC
SQ1-1309	1,309	RBI	T2 Upper - Right channel - returning ditch	4504220	461465	4/15/04 13:25	2.01	NC
SQ1-1371A	1,371	S	At old flume in stream	4504277	461445	4/15/04 9:13	3.30	64.0
SQ1-1371B	1,371	S	At old flume in stream	4504277	461445	4/15/04 9:14	3.30	64.0
SQ1-1452	1,452	S	T3 Upper - At diversion to wetland	4504334	461388	4/15/04 9:07	3.17	66.8
SQ1-1744	1,744	S	Irrigation ditch blw culvert near wetland; 2002 sample site	4504394	461305	4/15/04 9:26	NM	NM
			Middle injection reach					
SQ2-1601	1,601	S	T0 Middle - Injection site downstream from wetland culvert	4504379	461263	4/9/04 11:55	.11	70.9
SQ2-1843B	1,843	S	T1 Middle - At fence at end of wetland	4504455	461182	4/9/04 11:50	2.63	70.9
SQ2-1843C	1,843	S	T1 Middle - At fence at end of wetland	4504455	461182	4/9/04 11:51	2.58	70.9
SQ2-1843A	1,843	S	T1 Middle - At fence at end of wetland	4504455	461182	4/9/04 8:58	2.47	70.9
SQ2-1959	1,959	S	Upstream from tailings inflow - questioned chemistry	4504540	461108	4/9/04 11:57	2.49	70.9
SQ2-1965	1,965	RBI	Pond at end of long talings pile	4504550	461114	4/9/04 11:10	.14	NC
SQ2-2048	2,048	RBI	Location of several inflows	4504602	461073	4/9/04 11:04	2.58	NC
SQ2-2118	2,118	RBI	Homer Spring inflow to irrigation ditch; no input to stream	4504707	461143	4/9/04 11:08	.03	NM
SQ2-2171	2,171	S	Downstream from area of right bank inflows	4504698	461039	4/9/04 12:00	2.60	70.9
SQ2-2337	2,337	S	After braids have come back together	4504854	460993	4/9/04 12:07	2.64	70.9
SQ2-2387	2,387	LBI	Near tailings piles on right bank	4504904	460970	4/9/04 10:50	.91	NC

Table 2. Bromide conentration of synoptic water samples and characteristics of the sites at which the samples were collected, Silver Creek, Utah, April 2004—Continued.

Sample identifi- cation	Distance, (meters)	Source	Description	Northing, (meters)	Easting, (meters)	Sample date and time		Bromide, (mg/L)	Dis- charge, (L/s)
			Middle injection reach—Continued						
SQ2-2431	2,447	LBI	Drains large area with tailings off to left	4504936	460948	4/9/04	10:45	.24	NC
SQ2-2560	2,519	S	Between upstream left bank inflows and down- stream right bank inflows	4505061	460919	4/9/04	12:13	2.42	78.4
SQ2-2569	2,528	RBI	Drains from tailings pile	4505069	460916	4/9/04	10:42	< .03	NC
SQ2-2678	2,637	S	Downstream from tailings inflow; to collect inflows	4505174	460886	4/9/04	12:20	2.28	84.0
SQ2-2718	2,677	RBI	Pond from tailings drainage	4505213	460880	4/9/04	10:36	.17	NC
SQ2-2730	2,757	S	At fence below property corner	4505275	460870	4/9/04	12:24	2.14	86.5
SQ2-2785	2,847	S	Downstream from where stream cuts through corner of property	4505276	460872	4/9/04	12:33	2.32	88.3
SQ2-2780	2,892	RBI	Direct drainage from tailings pile with Ulothrix	4505410	460823	4/9/04	10:30	1.92	NC
SQ2-2810	2,927	S	At old skull in stream	4505430	460789	4/9/04	12:28	2.16	89.9
SQ2-3027	3,144	LBI	Drains flat area; no tailings piles visible	4505480	460761	4/9/04	10:19	1.37	NC
SQ2-3045	3,162	RBI	Draining from tailings piles	4505495	460766	4/9/04	10:17	1.82	NC
SQ2-3254B	3,371	S	T2 Middle - Upstream from old tree	4505676	460685	4/9/04	12:41	2.28	96.3
SQ2-3254A	3,371	S	T2 Middle - Upstream from old tree	4505676	460685	4/9/04	21:54	2.09	96.3
SQ2-3379	3,496	S	Downstream from area where stream is ponded	4505790	460634	4/9/04	12:46	2.00	98.1
SQ2-3598	3,715	RBI	Small pool on right bank; sample puddle	4505963	460558	4/9/04	10:04	.33	NC
SQ2-3602	3,719	LBI	Drains tailings to left of stream	4505965	460544	4/9/04	10:01	.84	NC
SQ2-3784A	3,901	S	Upstream from point where flow disperses; made a new diversion to right	4506113	460461	4/9/04	12:55	2.03	100
SQ2-3784B	3,901	S	Upstream from point where flow disperses; made a new diversion to right	4506113	460461	4/9/04	12:56	2.03	100
SQ2-4000	4,117	RBI	Inflow from natural channel; ditch from left of rail trail; strm water	4506264	460493	4/9/04	9:52	.81	NC
SQ2-4050	4,167	S	Location to check with discharge measurement and Br	4506351	460427	4/9/04	13:04	1.87	106
SQ2-4286	4,403	S	After gathering back together into channel; could be irrigation ditch	4506561	460311	4/9/04	13:10	1.75	116
SQ2-4292	4,409	LBI	Draining area where stream dispersd	4506560	460310	4/9/04	9:44	.25	NC
SQ2-0054	4,517	LBI	Draining wide area to left of stream	4506643	460231	4/9/04	9:40	.43	NC
SQ2-0061	4,800	S	Downstream from gathered dispersion	4506713	460011	4/9/04	13:19	2.22	122
SQ2-0080	5,251	S	Downstream from area where stream is ponded	4507164	460015	4/9/04	13:32	1.57	133
SQ2-0096	5,493	RBI	Drainage has some flow to stream; tailings in soil to right	4507409	460024	4/9/04	9:23	.35	NC
SQ2-0100	5,624	S	Downstream from possible tailings inflow	4507538	460003	4/9/04	13:39	1.49	143
SQ2-0108	5,833	RBI	Orange stained inflow	4507710	459965	4/9/04	9:15	< .03	NC
SQ2-0109	5,843	RBI	Draining tailings	4507703	459959	4/9/04	10:15	.26	NC
SQ2-0149	5,878	RBI	Sample away from stream; water not draining to stream	4507755	459965	4/9/04	9:12	< .03	NC
SQ2-0113	5,950	S	Upstream from many tailings mounds	4507805	459931	4/9/04	13:50	1.34	145
SQ2-0120	6,045	RBI	Draining tailings, maybe from storm, orange plume	4507870	459866	4/9/04	9:05	.06	
SQ2-0122	6,093	S	To account for inflows and separate tailings below	4507907	459836	4/9/04	13:55	1.87	146
SQ2-0135	6,322	S	T3 Middle - Upstream from pond above Prom- ontory Road	4508017	459664	4/9/04	14:04	1.45	147
SQ2-0137	6,353	RBI	Orange inflow; farther right	4508045	459653	4/9/04	8:55	.63	NC
SQ2-0005	7,259	S	End of middle injection reach	4508154	459567	4/9/04	14:12	1.48	177

Table 2   27

Table 2. Bromide conentration of synoptic water samples and characteristics of the sites at which the samples were collected, Silver Creek, Utah, April 2004—Continued.

Sample identification	Distance, (meters)	Source	Description	Northing, (meters)	Easting, (meters)	Sample date and time		Bromide, (mg/L)	Discharge, (L/s)
			Lower injection reach						
SQ3-005	7,142	S	T0 Lower - Injection site downstream from Promontory culvert	4508154	459567	4/6/04	12:20	.29	53.8
SQ3-008	7,161	S	First site downstream from injection for discharge	4508170	459557	4/6/04	12:22	7.37	53.8
SQ3-010	7,185	RBI	Draining tailings toward old "Big 4" mill site	4508186	459550	4/6/04	11:35	2.17	NC
SQ3-012	7,208	S	T1 Lower - Downstream from first tailings inflow	4508206	459530	4/6/04	12:30	7.78	53.8
SQ3-018	7,276	S	To capture right bank inflows	4508258	459504	4/6/04	12:35	7.52	55.8
SQ3-024	7,365	RBI	Ponds along berm line to east	4508333	459470	4/6/04	11:30	.08	NC
SQ3-025	7,366	LBI	Draing from pond toward BFI Disposal land	4508333	459462	4/6/04	11:25	.28	NC
SQ3-032	7,397	S	To capture both inflow upstream	4508385	459469	4/6/04	12:40	7.32	57.3
SQ3-039	7,470	S	Upstream from inflow from marsh draining along fence	4508519	459468	4/6/04	12:45	7.27	57.7
SQ3-042	7,491	LBI	Draining from marsh area along much of BFI land	4508512	459419	4/6/04	11:20	.85	NC
SQ3-048	7,571	S	Downstream from inflow along fence	4508596	459474	4/6/04	12:50	6.86	59.9
SQ3-056	7,687	S	Downstream from area where stream is ponded	4508682	459466	4/6/04	12:55	6.91	60.9
SQ3-060	7,730	LBI	Draining tailings toward old mill site; pool away from stream	4508724	459465	4/6/04	11:10	.76	NC
SQ3-066	7,825	S	Near right bank talings in flood plain	4508802	459510	4/6/04	13:00	6.91	60.9
SQ3-083	8,009	RBI	Small, unconnected pools along ditch	4508923	459558	4/6/04	11:05	.13	
SQ3-097	8,225	S	Downstream from tailings inflows on both sides of stream	4509047	459627	4/6/04	13:10	6.92	60.9
SQ3-115	8,449	RBI	Pond on right bank away from stream	4509256	459651	4/6/04	10:50	.13	NC
SQ3-121	8,497	LBI	Draining in small grassy channel	4509258	459596	4/6/04	10:45	.27	NC
SQ3-127	8,591	S	Gathering of the upstream inflows	4509340	459649	4/5/04	13:15	7.22	60.9
SQ3-131	8,701	LBI	Pond by waste-water treatment plant	4509394	459683	4/6/04	10:38	.13	NC
SQ3-140	8,862	S	T2 Lower - Upstream from waste-water treatment plant inflow	4509453	459779	4/6/04	13:22	7.29	60.9
SQ3-141	8,881	LBI	Discharge from waste-water treatment plant	4509467	459792	4/6/04	10:22	.13	NC
SQ3-142	8,886	RBI	Drains area to right including pond	4509471	459795	4/6/04	10:11	.11	NC
SQ3-145	8,909	S	Stream below gage and waste-water treatment plant inflow	4509493	459803	4/5/04	13:34	3.99	96.3
SQ3-172	9,355	S	Upstream from irrigation return flow	4509894	459888	4/6/04	13:45	4.50	96.3
SQ3-173	9,360	RBI	Return flow from irrigation ditch, through dairy farm	4509899	459889	4/6/04	9:54	.40	NC
SQ3-178A	9,438	S	Downstream from irrigation return flow	4509965	459867	4/6/04	13:48	4.22	103
SQ3-178B	9,438	S	Downstream from irrigation return flow	4509965	459867	4/6/04	13:50	4.22	103
SQ3-186	9,562	LBI	Discharge from stream on left	4510076	459820	4/6/04	9:48	.03	NC
SQ3-189	9,598	LBI	Seep inflow of very high conductance	4510111	459829	4/6/04	9:45	.13	NC
SQ3-193	9,719	S	Dowstream from high conductance seeps	4510190	459901	4/6/04	13:58	3.81	115
SQ3-194	9,725	RBI	Draining dairy farm	4510194	459905	4/6/04	9:34	.06	NC
SQ3-196	9,747	S	T3 Lower - Downstream from bridge to dairy	4510215	459905	4/6/04	14:00	3.65	121

Table 3. Concentration of major ions in synoptic water samples collected along Silver Creek, Utah, April 2004.

[Source: S, stream; LBI, left-bank inflow; RBI, right-bank inflow; Filter: FA, filtered acidified; RA, unfiltered acidified; Temperature: °C, degrees Celsius; pH, in standard units; mg/L, milligrams per liter; NV, no value; <, less than; NR, not recorded]

Sample identification	Distance (meters)	Source	Filter	Temperature (°C)	pH	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Alkalinity as CaCO3 (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Silica as Si (mg/L)
SQ1-0000	0	S	FA	7.0	8.06	158	40.1	153	3.06	135	286	354	3.53
SQ1-0061	61	LBI	FA	9.0	7.68	231	54.5	117	2.33	188	424	332	8.25
SQ1-0101	101	S	FA	7.5	8.04	158	39.7	153	2.91	137	287	357	3.65
SQ1-0250	250	S	FA	7.5	8.01	159	40.1	156	2.87	134	286	361	3.65
SQ1-0428A	428	S	FA	7.0	8.04	166	41.4	160	2.91	132	291	367	3.68
SQ1-0428B	428	S	FA	7.0	8.01	163	41.0	158	2.90	134	293	365	3.72
SQ1-0525	525	S	FA	7.0	8.08	162	40.6	157	2.86	135	291	369	3.96
SQ1-0625	625	LBI	FA	7.0	7.89	194	47.4	152	3.36	141	318	383	4.76
SQ1-0681	672	LBI	FA	6.5	7.60	225	58.5	238	3.17	150	270	687	6.76
SQ1-0682	682	LBI	FA	9.0	6.94	267	67.8	213	2.28	174	551	568	9.41
SQ1-0731	731	S	FA	6.5	7.93	168	42.1	166	3.03	137	297	393	4.04
SQ1-0757	757	LBI	FA	7.0	7.95	172	42.8	169	2.92	137	297	392	3.48
SQ1-0770	770	LBI	FA	7.0	7.62	463	96.8	646	3.14	156	194	1,880	7.90
SQ1-0861	861	S	FA	6.0	7.82	179	41.9	123	2.92	160	337	281	6.09
SQ1-1050	1,050	RBI	FA	6.0	7.87	218	45.2	130	5.71	178	322	379	NV
SQ1-1095	1,095	S	FA	6.0	8.01	177	43.9	177	3.04	138	295	426	4.01
SQ1-1148	1,148	RBI	FA	5.5	7.90	189	46.0	182	3.03	141	309	442	3.86
SQ1-1229	1,229	S	FA	5.0	7.84	185	42.9	123	3.23	165	344	291	7.11
SQ1-1235	1,235	RBI	FA	5.0	7.35	286	72.6	116	4.03	157	761	307	12.2
SQ1-1300	1,300	S	FA	6.0	7.96	182	44.3	178	3.03	141	304	434	4.12
SQ1-1309	1,309	RBI	FA	5.5	7.81	184	42.2	120	3.22	167	344	294	7.45
SQ1-1371A	1,371	S	FA	5.5	7.91	185	43.9	158	3.12	149	316	374	4.95
SQ1-1371B	1,371	S	FA	5.5	7.97	184	43.9	157	3.11	148	315	375	5.00
SQ1-1452	1,452	S	FA	5.5	7.98	181	43.6	154	2.97	149	320	375	5.10
SQ2-1601	1,601	S	FA	NR	8.12	163	39.4	143	3.30	141	302	338	6.73
SQ1-1744	1,744	S	FA	4.0	7.25	230	60.2	152	3.70	158	525	386	9.98
SQ2-1843A	1,843	S	FA	NR	8.12	167	39.4	160	3.40	144	292	361	6.63
SQ2-1843B	1,843	S	FA	NR	8.03	166	39.8	152	3.44	144	301	360	6.64
SQ2-1843C	1,843	S	FA	NR	7.95	167	39.9	153	3.34	144	300	359	6.67
SQ2-1959	1,959	S	FA	NR	8.19	169	40.5	154	3.55	145	302	362	6.77
SQ2-1965	1,965	RBI	FA	NR	3.36	479	286	177	4.26	< .5	3,510	492	29.7
SQ2-2048	2,048	RBI	FA	NR	7.79	174	40.3	144	3.57	138	343	332	7.22
SQ2-2118	2,118	RBI	FA	NR	8.16	44.1	10.4	17.1	2.29	125	9.41	39.7	21.8
SQ2-2171	2,171	S	FA	NR	8.07	172	40.1	156	3.53	140	319	371	6.93
SQ2-2337	2,337	S	FA	NR	8.03	175	41.5	157	3.59	142	318	374	7.23
SQ2-2431	2,447	LBI	FA	NR	7.95	179	47.4	123	4.13	194	104	454	8.72
SQ2-2560	2,519	S	FA	NR	8.01	179	42.4	154	3.59	140	321	386	7.34
SQ2-2569	2,528	RBI	FA	NR	7.03	275	67.0	140	7.16	127	730	361	15.8
SQ2-2678	2,637	S	FA	NR	7.98	180	42.4	154	3.57	141	330	381	7.39
SQ2-2718	2,677	RBI	FA	NR	7.31	247	61.9	116	4.84	176	604	301	14.7
SQ2-2730	2,757	S	FA	NR	7.94	184	43.3	154	3.69	141	332	384	7.56
SQ2-2785	2,847	S	FA	NR	7.94	186	43.5	155	3.71	142	331	382	7.67
SQ2-2780	2,892	RBI	FA	NR	7.80	198	45.6	152	4.22	138	365	380	8.85
SQ2-2810	2,927	S	FA	NR	7.94	184	43.5	155	3.75	139	331	383	7.59
SQ2-3027	3,144	LBI	FA	NR	7.80	193	47.1	128	4.40	142	336	363	9.82
SQ2-3045	3,162	RBI	FA	NR	7.76	213	48.8	148	4.71	137	411	374	9.49
SQ2-3254A	3,371	S	FA	NR	7.91	188	44.3	153	3.90	141	335	378	7.86
SQ2-3254B	3,371	S	FA	NR	7.97	187	43.9	152	3.69	141	341	377	7.83
SQ2-3379	3,496	S	FA	NR	7.94	190	44.8	153	3.72	141	343	380	7.95
SQ2-3598	3,715	RBI	FA	NR	7.27	438	117	185	10.1	85.7	1,300	469	8.45
SQ2-3602	3,719	LBI	FA	NR	7.35	247	63.2	123	4.09	121	600	370	12.1
SQ2-3784A	3,901	S	FA	NR	7.98	190	44.7	149	3.61	141	355	383	7.93
SQ2-3784B	3,901	S	FA	NR	7.96	192	45.2	152	3.55	141	355	383	8.09

Table 3   29

Table 3. Concentration of major ions in synoptic water samples collected along Silver Creek, Utah, April 2004—Continued.

Sample identifi-cation	Distance (meters)	Source	Filter	Temp-erature (°C)	pH	Calcium (mg/L)	Magne-sium (mg/L)	Sodium (mg/L)	Potas-sium (mg/L)	Alkalinity as CaCO$_3$ (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Silica as Si (mg/L)
SQ2-4000	4,117	RBI	FA	NR	7.79	208	48.2	140	3.77	151	402	370	9.04
SQ2-4050	4,167	S	FA	NR	7.99	202	47.5	150	3.83	142	380	376	8.52
SQ2-4286	4,403	S	FA	NR	8.02	200	46.9	148	3.80	142	378	380	8.45
SQ2-4292	4,409	LBI	FA	NR	7.61	271	69.8	146	4.72	134	601	458	8.69
SQ2-0054	4,517	LBI	FA	NR	7.81	306	82.7	162	5.51	154	475	638	11.6
SQ2-0061	4,800	S	FA	NR	8.01	205	48.2	151	3.87	141	376	384	8.44
SQ2-0080	5,251	S	FA	NR	7.96	213	49.9	152	4.27	143	388	390	8.76
SQ2-0096	5,493	RBI	FA	NR	7.57	294	70.1	107	4.63	141	667	345	12.4
SQ2-0100	5,624	S	FA	NR	7.88	232	53.5	146	4.33	141	437	389	9.05
SQ2-0108	5,833	RBI	FA	NR	7.65	237	50.4	61.0	3.76	132	556	215	13.3
SQ2-0109	5,843	RBI	FA	NR	7.32	321	76.7	68.4	6.28	109	1,040	181	14.3
SQ2-0149	5,878	RBI	FA	NR	5.98	453	181	104	20.0	24.9	3,250	301	15.1
SQ2-0113	5,950	S	FA	NR	7.86	238	55.2	145	4.40	140	452	386	9.29
SQ2-0120	6,045	RBI	FA	NR	4.13	436	154	145	9.36	< .1	3,680	136	28.7
SQ2-0122	6,093	S	FA	NR	7.83	231	53.9	141	4.46	141	457	381	9.42
SQ2-0135	6,322	S	FA	NR	7.83	236	55.3	144	4.32	140	460	384	9.35
SQ2-0137	6,353	RBI	FA	NR	7.46	271	70.8	72.2	11.4	53.2	988	141	15.7
SQ2-0005	7,120	S	FA	NR	7.88	233	54.0	139	4.57	134	475	383	9.60
SQ3-005	7,142	S	FA	10.5	7.97	239	61.8	147	4.49	144	538	409	10.0
SQ3-008	7,161	S	FA	10.5	7.97	231	62.0	148	4.34	146	535	407	9.72
SQ3-008	7,161	S	RA	10.5	7.97	243	62.7	149	4.35	146	535	407	9.98
SQ3-010	7,185	RBI	FA	12.0	7.54	429	88.4	167	6.22	120	1,120	435	9.33
SQ3-010	7,185	RBI	RA	12.0	7.54	424	88.4	165	6.03	120	1,120	435	8.79
SQ3-012	7,208	S	FA	11.0	7.93	235	61.8	152	4.51	138	533	412	9.77
SQ3-018	7,276	S	FA	10.5	7.92	241	63.0	150	4.49	142	541	413	9.83
SQ3-024	7,365	RBI	FA	14.0	7.42	311	68.0	53.1	7.70	78.3	1,050	81.1	9.46
SQ3-025	7,366	LBI	FA	7.0	7.09	510	123	121	6.59	80.2	1,610	423	11.0
SQ3-032	7,397	S	FA	10.5	7.93	241	62.2	153	4.53	138	542	407	9.99
SQ3-032	7,397	S	RA	10.5	7.93	240	61.8	147	4.37	138	542	407	9.83
SQ3-039	7,470	S	FA	10.5	7.95	244	62.4	152	4.42	143	438	404	9.97
SQ3-042	7,491	LBI	FA	12.0	7.69	234	65.8	185	4.17	173	333	549	13.5
SQ3-048	7,571	S	FA	10.0	8.05	237	61.4	150	4.60	143	544	408	9.84
SQ3-056	7,687	S	FA	9.5	8.11	239	62.6	150	4.56	141	546	414	10.2
SQ3-060	7,730	LBI	FA	7.5	6.89	537	127	221	6.69	177	1,480	645	11.9
SQ3-060	7,730	LBI	RA	7.5	6.89	532	128	218	6.53	177	1,480	645	11.6
SQ3-066	7,825	S	FA	10.0	8.10	238	61.4	149	4.49	141	552	407	9.96
SQ3-083	8,009	RBI	FA	15.0	7.53	461	89.8	94.4	10.5	96.6	1,450	177	7.27
SQ3-097	8,225	S	FA	10.0	8.12	243	62.0	151	4.55	139	554	406	10.5
SQ3-115	8,449	RBI	FA	5.0	7.59	52.9	10.6	24.0	.85	33.5	131	58.1	2.25
SQ3-121	8,497	LBI	FA	11.0	7.50	346	73.2	140	4.93	116	976	349	11.5
SQ3-127	8,591	S	FA	10.0	8.12	242	63.1	147	4.52	147	568	409	9.95
SQ3-127	8,591	S	RA	10.0	8.12	239	61.2	144	4.07	147	568	409	9.64
SQ3-131	8,701	LBI	FA	12.0	7.80	222	45.5	124	5.06	146	516	271	8.47
SQ3-140	8,862	S	FA	10.5	8.13	261	64.6	156	4.75	142	567	411	10.2
SQ3-141	8,881	LBI	FA	12.0	8.24	156	39.7	211	11.8	147	268	399	11.0
SQ3-142	8,886	RBI	FA	7.0	7.93	260	58.8	74.5	3.02	206	521	262	13.0
SQ3-145	8,909	S	FA	12.0	8.15	223	51.5	164	6.74	145	441	403	9.91
SQ3-145	8,909	S	RA	12.0	8.15	227	53.1	170	7.43	145	441	403	10.2
SQ3-172	9,355	S	FA	12.5	8.12	237	55.1	161	6.66	142	467	397	10.5
SQ3-173	9,360	RBI	FA	7.5	7.91	201	49.3	62.5	6.11	188	310	247	15.9
SQ3-178A	9,438	S	FA	13.0	7.87	235	54.6	158	6.74	145	458	385	11.0
SQ3-178A	9,438	S	RA	13.0	7.87	239	55.2	157	6.56	145	458	385	11.2
SQ3-178B	9,438	S	FA	13.0	8.12	235	54.2	154	6.57	147	460	384	10.8
SQ3-178B	9,438	S	RA	13.0	8.12	260	65.4	151	4.93	147	460	384	10.6
SQ3-186	9,562	LBI	FA	9.5	7.92	67.4	16.8	26.2	3.24	161	51.5	55.9	18.2

Table 3. Concentration of major ions in synoptic water samples collected along Silver Creek, Utah, April 2004—Continued.

Sample identifi- cation	Distance (meters)	Source	Filter	Temp- erature (°C)	pH	Calcium (mg/L)	Magne- sium (mg/L)	Sodium (mg/L)	Potas- sium (mg/L)	Alkalinity as CaCO$_3$ (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Silica as Si (mg/L)
SQ3-189	9,598	LBI	FA	7.5	7.75	438	121	286	50.4	279	29.0	1,400	15.9
SQ3-193	9,719	S	FA	13.0	7.82	221	51.8	145	6.50	148	422	363	11.7
SQ3-193	9,719	S	RA	13.0	7.82	220	51.4	144	6.35	148	422	363	11.8
SQ3-194	9,725	RBI	FA	7.0	7.64	107	20.4	24.5	10.6	230	107	61.1	16.8
SQ3-196	9,747	S	FA	13.5	7.89	208	49.4	147	6.88	147	409	361	12.1
SQ3-196	9,747	S	RA	13.5	7.89	216	50.4	144	6.63	147	409	361	11.9

Table 4. Concentration of trace elements in synoptic water samples collected along Silver Creek, Utah, April 2004.

[Distance, in meters along the study reach; Source: S, stream; LBI, left-bank inflow; RBI, right-bank inflow; Filter: FA, 0.45-micrometer filtration; RA, unfiltered acidified; chemical concentrations reported in micrograms per liter; <, less than]

Sample identification	Dis-tance	Source	Fil-ter	Alumi-num	Arse-nic	Bari-um	Cad-mium	Co-balt	Chro-mium	Cop-per	Iron	Lead	Manga-nese	Molyb-denum	Nickel	Sil-ver	Stron-tium	Ura-nium	Vana-dium	Zinc
										Upper injection reach										
SQ1-0000	0	S	FA	14.6	2.13	66.2	2.69	0.59	0.47	1.96	13.2	1.62	308	1.50	2.63	0.01	767	1.96	0.133	1,300
SQ1-0061	61	LBI	FA	14.1	1.98	67.0	24.0	.65	.36	1.63	2.55	.347	428	1.29	4.35	<.01	1,260	2.71	.404	8,800
SQ1-0101	101	S	FA	15.1	1.97	68.2	2.66	.65	.45	2.20	5.57	.813	369	1.51	2.96	<.01	779	1.98	.130	1,340
SQ1-0250	250	S	FA	13.9	1.95	68.1	2.83	.65	.36	1.98	14.4	1.36	373	1.47	3.49	<.01	779	1.99	.129	1,410
SQ1-0428A	428	S	FA	12.9	1.99	66.2	4.22	.66	.25	1.96	19.0	2.09	371	1.41	2.62	<.01	776	1.97	.128	1,620
SQ1-0428B	428	S	FA	12.3	2.06	69.7	4.08	.68	.45	1.88	21.9	2.13	379	1.48	2.79	<.01	766	2.05	.129	1,680
SQ1-0525	525	S	FA	12.7	2.04	68.8	4.09	.69	.44	2.11	18.8	1.87	369	1.48	2.96	.01	783	2.02	.127	1,620
SQ1-0625	625	LBI	FA	25.6	2.21	65.1	3.48	.41	.49	2.16	132	4.38	230	1.29	7.09	.02	955	2.09	.126	1,690
SQ1-0681	672	LBI	FA	13.2	4.38	130	<.09	.90	.58	.62	629	.160	642	1.11	.56	.02	1,300	2.51	.408	204
SQ1-0682	682	LBI	FA	13.5	9.75	90.7	3.54	2.24	.69	1.09	1,390	.835	1,920	5.67	3.44	.02	1,630	1.88	.341	5,110
SQ1-0731	731	S	FA	13.4	2.58	71.0	2.89	.51	.60	1.55	37.5	.948	302	1.45	2.54	<.01	839	2.01	.118	1,510
SQ1-0757	757	LBI	FA	13.1	2.46	66.2	2.72	.42	.27	1.88	17.4	1.04	252	1.37	2.21	<.01	809	1.98	.119	1,390
SQ1-0770	770	LBI	FA	13.4	1.96	443	1.42	.34	1.22	1.49	30.8	3.06	74.0	1.46	.62	.28	2,710	6.24	.764	352
SQ1-0861	861	S	FA	3.98	2.28	48.7	.81	.27	.77	1.22	50.3	.501	184	1.18	1.56	.01	825	2.06	.145	932
SQ1-1050	1,050	RBI	FA	13.2	7.50	113	.54	2.06	.52	1.63	96.5	.269	<5	2.57	2.40	<.01	1,100	2.12	.782	757
SQ1-1095	1,095	S	FA	14.8	2.80	78.4	2.89	.53	.37	1.64	35.6	1.32	328	1.44	2.54	.01	873	2.06	.116	1,560
SQ1-1148	1,148	RBI	FA	37.5	3.43	73.3	9.66	.50	.59	5.59	160	17.2	309	1.50	2.37	.08	937	2.10	.231	2,160
SQ1-1229	1,229	S	FA	13.5	3.13	54.3	.76	.53	.53	1.31	50.4	.539	419	1.33	1.80	.01	840	2.05	.156	1,010
SQ1-1235	1,235	RBI	FA	14.9	.54	40.7	77.1	1.27	.54	9.52	18.2	.922	743	.37	13.0	.03	1,310	1.02	.028	25,500
SQ1-1300	1,300	S	FA	13.2	2.65	77.3	4.88	.54	.41	2.05	17.6	2.03	337	1.81	2.63	.03	894	2.09	.120	1,950
SQ1-1309	1,309	RBI	FA	12.9	3.10	56.1	.64	.55	.65	1.33	41.3	.714	419	1.36	1.91	<.01	853	2.13	.156	979
SQ1-1371A	1,371	S	FA	11.6	2.80	68.2	3.45	.53	.21	2.06	27.2	1.85	367	1.37	2.28	<.01	876	2.07	.143	1,560
SQ1-1371B	1,371	S	FA	11.9	2.48	68.6	3.40	.53	.25	2.05	24.6	1.67	369	1.39	2.34	.01	867	2.07	.136	1,570
SQ1-1452	1,452	S	FA	13.8	2.66	70.9	3.33	.54	.36	3.06	18.3	1.61	378	1.42	2.52	<.01	886	2.14	.145	1,690
SQ2-1601	1,601	S	FA	4.35	2.70	54.7	9.62	.76	.47	3.39	16.4	1.62	269	1.47	2.68	.01	714	2.01	.249	2,380
SQ1-1744	1,744	S	FA	15.1	13.8	48.9	28.2	4.33	.68	4.37	362	.736	1,150	1.69	6.97	.03	1,250	2.29	.107	7,120
										Middle injection reach										
SQ2-1843A	1,843	S	FA	3.45	2.83	56.0	12.7	.54	.31	3.66	12.6	2.35	220	1.53	2.78	.02	714	2.12	.271	2,440
SQ2-1843B	1,843	S	FA	2.60	2.90	56.3	12.8	.63	.40	4.08	19.5	2.92	233	1.54	2.54	.03	735	2.08	.292	2,380
SQ2-1843C	1,843	S	FA	2.59	2.90	55.8	12.9	.63	.37	4.04	22.2	3.10	234	1.50	2.62	.03	726	2.11	.283	2,380
SQ2-1959	1,959	S	FA	1.65	2.93	130	<.09	.10	.23	.56	91.4	.510	241	.24	.44	<.01	258	.586	3.71	2,470
SQ2-1965	1,965	RBI	FA	37,000	2.55	9.91	1014	318	10.5	959	34,400	892	23,600	.09	346	1.20	1,620	12.8	.944	270,000
SQ2-2048	2,048	S	FA	35.1	1.41	49.8	22.0	2.52	.34	6.24	94.8	.941	308	1.41	5.10	.02	672	1.93	.147	4,350
SQ2-2118	2,118	RBI	FA	4.79	2.64	56.9	13.0	.71	.42	4.32	16.2	2.71	36.3	1.49	2.94	.02	820	2.12	.284	26
SQ2-2171	2,171	S	FA	25.6	1.83	58.3	18.8	2.24	.39	5.90	15.5	1.71	313	1.52	4.44	.01	752	2.23	.229	3,350
SQ2-2337	2,337	S	FA	25.1	2.01	58.5	19.4	2.30	.35	6.80	28.5	4.34	305	1.61	5.01	.04	746	2.36	.237	3,380
SQ2-2431	2,447	LBI	FA	1.78	8.99	145	19.7	.19	.41	8.59	6.00	3.12	48.3	3.37	1.43	.04	1,020	6.02	1.11	1,590
SQ2-2560	2,519	S	FA	28.6	1.66	60.3	18.9	3.24	.32	6.78	21.2	1.76	300	1.66	6.56	.02	854	2.46	.236	3,360
SQ2-2569	2,528	RBI	FA	26.2	2.10	44.7	73.7	14.2	.35	74.3	350	35.8	399	1.23	29.0	.08	1,370	2.14	.063	11,300
SQ2-2678	2,637	S	FA	30.2	1.43	59.9	19.9	3.51	.37	6.59	21.2	1.42	309	1.64	5.87	.01	801	2.42	.217	3,470
SQ2-2718	2,677	RBI	FA	8.48	3.14	48.2	40.1	8.66	.33	18.2	103	5.26	554	1.60	14.1	.06	1,270	4.98	.571	6,110

Table 4   31

Table 4. Concentration of trace elements in synoptic water samples collected along Silver Creek, Utah, April 2004—Continued.

Sample identification	Distance	Source	Filter	Aluminum	Arsenic	Barium	Cadmium	Cobalt	Chromium	Copper	Iron	Lead	Manganese	Molybdenum	Nickel	Silver	Strontium	Uranium	Vanadium	Zinc
SQ2-2730	2,757	S	FA	31.2	1.61	57.7	21.1	3.65	.26	7.60	48.7	2.45	314	1.62	6.20	.04	737	2.35	.194	3,580
									Middle injection reach—Continued												
SQ2-2785	2,847	S	FA	29.9	1.58	61.3	21.5	3.69	.30	7.01	21.5	1.49	317	1.69	6.80	.02	819	2.56	.219	3,590
SQ2-2780	2,892	RBI	FA	13.7	3.17	56.2	29.1	2.91	.28	7.25	28.2	1.60	305	1.70	6.32	.04	888	2.55	.240	4,690
SQ2-2810	2,927	S	FA	28.2	1.59	59.7	21.4	3.60	.34	7.00	22.2	1.54	315	1.64	6.07	.02	831	2.48	.213	3,740
SQ2-3027	3,144	LBI	FA	6.53	8.71	.65.2	26.0	1.15	.29	9.10	25.6	3.10	152	1.74	4.01	.05	977	2.43	.306	3,320
SQ2-3045	3,162	RBI	FA	8.20	4.67	53.7	32.2	2.63	.32	8.39	32.5	2.54	348	1.64	5.73	.05	965	2.57	.232	4,840
SQ2-3254A	3,371	S	FA	21.6	1.95	54.9	23.2	3.56	.29	7.04	24.3	1.62	317	1.56	6.26	.04	715	2.33	.175	4,230
SQ2-3254B	3,371	S	FA	26.0	1.85	59.9	22.6	3.68	.38	7.60	22.6	1.79	315	1.73	6.12	.02	861	2.46	.220	3,840
SQ2-3379	3,496	S	FA	25.9	1.82	61.1	22.8	4.21	.38	7.31	28.6	1.77	329	2.10	7.45	.03	864	2.55	.210	3,960
SQ2-3598	3,715	RBI	FA	15.1	2.08	89.1	155	36.3	.43	19.8	129	4.31	3,540	2.99	20.3	.28	2,030	3.22	.063	24,400
SQ2-3602	3,719	LBI	FA	15.1	5.66	71.6	62.8	7.58	.35	16.8	125	13.7	658	1.72	12.5	.04	1,280	2.11	.209	11,300
SQ2-3784A	3,901	S	FA	24.7	1.94	61.9	24.3	4.52	.38	7.73	21.8	1.62	341	1.71	7.58	.02	878	2.53	.213	4,150
SQ2-3784B	3,901	S	FA	25.3	1.84	61.4	24.6	4.51	.41	7.75	23.2	1.70	346	1.69	7.65	.02	894	2.55	.216	4,200
SQ2-4000	4,117	RBI	FA	9.85	4.37	58.8	26.7	3.77	.48	7.95	48.9	6.74	484	1.89	5.96	.05	982	2.60	.281	4,840
SQ2-4050	4,167	S	FA	14.8	2.81	58.9	25.8	4.23	.29	8.21	21.9	2.73	373	1.77	6.96	.03	840	2.44	.232	4,390
SQ2-4286	4,403	S	FA	14.3	2.82	60.5	25.7	4.03	.35	7.62	24.4	3.17	366	1.69	7.24	.03	913	2.59	.247	4,250
SQ2-4292	4,409	LBI	FA	1.55	9.41	65.2	60.6	1.09	.66	16.1	17.8	13.5	258	2.81	7.78	.14	1,280	2.73	.127	8,400
SQ2-0054	4,517	LBI	FA	2.16	18.2	113	23.4	.44	.32	7.81	12.6	4.74	160	1.83	2.99	.06	1,710	3.21	.333	2,600
SQ2-0061	4,800	S	FA	13.3	3.31	63.0	26.3	4.02	.43	7.89	20.8	3.75	368	1.79	7.23	.03	967	2.67	.257	4,250
SQ2-0080	5,251	S	FA	3.60	6.59	61.2	23.4	2.43	.24	12.5	19.0	2.85	271	1.98	6.19	.03	1,040	2.67	.270	3,450
SQ2-0096	5,493	RBI	FA	3.53	6.77	50.4	38.4	5.75	.30	9.76	76.8	6.13	1,950	2.32	8.32	.02	1,510	2.62	.101	8,380
SQ2-0100	5,624	S	FA	3.59	7.33	58.4	27.3	2.55	.86	8.03	33.8	4.12	506	2.02	5.23	.04	1,130	2.55	.244	4,460
SQ2-0108	5,833	RBI	FA	2.25	6.70	23.0	4.74	1.47	.24	3.28	30.4	.574	619	1.15	3.10	.01	1,100	1.31	.035	3,440
SQ2-0109	5,843	RBI	FA	2.34	3.47	26.3	188	6.00	.28	16.4	144	7.70	2,010	.85	21.2	.14	1,540	1.72	.035	53,400
SQ2-0149	5,878	RBI	FA	337	16.5	33.4	2038	229	.42	33.5	1,910	104	10,900	2.15	281	.49	1,320	.068	.064	1,070,000
SQ2-0113	5,950	S	FA	3.60	6.75	56.0	28.5	2.63	.49	7.90	24.3	3.00	552	1.92	5.98	.03	1,130	2.52	.221	5,140
SQ2-0120	6,045	RBI	FA	9,520	20.3	34.8	562	278	2.62	304	63,000	539	9,860	.02	221	.06	2,340	1.45	.331	132,000
SQ2-0122	6,093	S	FA	12.7	5.11	57.3	30.7	3.43	.41	8.77	65.1	3.31	597	1.96	7.33	.03	1,150	2.59	.209	5,600
SQ2-0135	6,322	S	FA	10.5	4.55	56.4	31.8	3.50	.53	8.55	29.8	2.04	644	1.93	7.10	.02	1,150	2.57	.193	6,110
SQ2-0137	6,353	RBI	FA	7.01	7.53	58.2	151	20.9	.27	24.5	58.8	4.61	4,080	2.08	26.7	.06	1,340	1.01	.094	45,300
SQ2-0005	7,120	S	FA	11.9	4.30	58.0	34.5	3.76	.31	8.99	43.2	3.26	754	1.97	7.89	.05	1,180	2.65	.196	6,890
									Lower injection reach												
SQ3-005	7,142	S	FA	8.36	4.26	60.6	38.1	4.92	.19	10.2	17.9	2.83	952	2.26	8.62	.03	1,250	2.80	.184	6,800
SQ3-008	7,161	S	FA	7.88	4.33	62.6	38.7	5.00	.24	10.3	18.5	3.02	945	2.29	8.69	.03	1,280	2.89	.184	6,800
SQ3-008	7,161	S	RA	37.2	10.1	63.0	39.1	5.17	<.15	14.2	433	35.1	959	2.39	8.97	.30	1,220	2.94	.308	7,130
SQ3-010	7,185	RBI	FA	2.52	2.71	92.2	183	3.47	.27	11.0	6.05	5.85	1,980	1.67	12.4	.07	2,100	2.87	.117	30,100
SQ3-010	7,185	RBI	RA	15.3	4.31	91.5	190	3.51	.11	13.3	95.0	15.8	1,960	1.69	12.9	.38	1,940	2.89	.154	30,000
SQ3-012	7,208	S	FA	8.07	4.54	62.8	37.0	4.95	.22	10.1	22.4	3.30	950	2.30	8.58	.03	1,330	2.93	.191	6,730
SQ3-018	7,276	S	FA	7.79	4.55	61.8	38.9	4.82	.29	10.2	24.8	3.55	940	2.23	8.42	.02	1,250	2.90	.176	6,890
SQ3-024	7,365	RBI	FA	2.15	5.15	69.7	117	2.13	.21	21.9	21.3	76.9	2,200	2.24	6.37	.35	1,370	.984	.029	26,300
SQ3-025	7,366	LBI	FA	2.72	2.90	48.8	224	3.80	.28	20.3	7.63	15.1	1,040	.85	17.5	.09	2,630	1.78	.094	44,800
SQ3-032	7,397	S	FA	7.10	4.45	60.1	38.0	4.69	.16	10.0	19.4	3.37	935	2.25	8.46	.02	1,300	2.81	.185	7,370
SQ3-032	7,397	S	RA	33.8	9.92	62.4	41.0	4.91	.05	14.3	409	34.7	920	2.29	8.96	.30	1,190	2.93	.300	7,510

Table 4. Concentration of trace elements in synoptic water samples collected along Silver Creek, Utah, April 2004—Continued.

Sample identification	Dis-tance	Source	Fil-ter	Alumi-num	Arse-nic	Bari-um	Cad-mium	Co-balt	Chro-mium	Cop-per	Iron	Lead	Manga-nese	Molyb-denum	Nickel	Sil-ver	Stron-tium	Ura-nium	Vana-dium	Zinc
SQ3-039	7,470	S	FA	6.40	4.47	61.0	40.3	4.69	.22	10.7	18.9	3.57	952	2.25	8.38	.02	1,320	2.74	.187	7,930
										Lower injection reach—Continued										
SQ3-042	7,491	LBI	FA	2.03	4.42	86.7	7.27	.27	.31	2.39	3.37	.840	144	1.91	6.15	.02	1,400	8.33	.981	8,740
SQ3-048	7,571	S	FA	6.68	4.60	63.2	40.5	4.63	.25	10.8	18.6	3.78	932	2.25	8.54	.03	1,320	3.00	.206	7,880
SQ3-056	7,687	S	FA	5.92	4.45	62.3	42.8	4.56	.24	11.1	16.8	3.75	944	2.23	8.98	.03	1,280	2.89	.199	8,420
SQ3-060	7,730	LBI	FA	2.33	3.82	32.9	462	9.81	.32	478	6.34	100	6,200	3.97	36.5	.29	2,480	3.61	.036	117,000
SQ3-060	7,730	LBI	RA	3.59	4.02	32.4	478	9.97	.19	508	17.1	103	6,200	3.95	38.5	.55	2,370	3.66	.039	117,000
SQ3-066	7,825	S	FA	5.57	4.46	63.3	40.9	4.35	.20	11.0	14.3	3.82	902	2.31	8.52	.03	1,380	2.92	.199	8,420
SQ3-083	8,009	RBI	FA	3.54	9.70	94.4	134	8.47	.24	15.5	111	33.2	3,970	3.69	7.72	.38	1,780	1.68	.089	25,200
SQ3-097	8,225	S	FA	4.61	4.43	62.7	42.9	4.05	.19	11.2	17.0	4.49	884	2.30	8.54	.03	1,340	2.92	.201	8,420
SQ3-115	8,449	RBI	FA	2.24	17.9	11.6	16.9	1.07	.38	1.37	116	1.17	636	1.05	1.89	.01	201	.236	<.01	9,150
SQ3-121	8,497	LBI	FA	2.06	4.37	60.3	189	1.87	.20	13.5	12.5	18.0	1,540	1.98	10.3	.10	1,800	2.35	.085	46,000
SQ3-127	8,591	S	FA	5.08	4.36	63.6	48.6	4.22	.24	12.6	24.2	7.89	885	2.30	8.78	.03	1,310	2.87	.179	9,280
SQ3-127	8,591	S	RA	24.5	8.95	61.9	47.5	3.80	<.05	16.1	321	40.0	856	2.28	8.66	.27	1,240	2.90	.277	9,310
SQ3-131	8,701	LBI	FA	1.66	7.16	38.6	31.4	4.41	.23	8.56	17.5	13.9	3,050	4.07	6.51	.06	954	2.19	.083	14,800
SQ3-140	8,862	S	FA	3.58	4.29	64.1	46.7	3.75	.26	12.4	14.5	7.73	936	2.33	8.45	.02	1,380	2.89	.190	9,040
SQ3-141	8,881	LBI	FA	8.36	4.86	51.0	0.81	.33	.42	4.51	22.4	2.59	60.9	14.2	2.46	.03	782	1.49	.889	357
SQ3-142	8,886	RBI	FA	1.67	9.24	34.8	1.35	.61	.20	2.87	24.9	.366	347	2.33	1.52	<.01	1,230	6.07	.258	765
SQ3-145	8,909	S	FA	6.09	4.84	56.7	25.3	2.10	.29	8.81	14.2	2.79	518	7.26	5.70	.03	1,090	2.45	.550	4,370
SQ3-145	8,909	S	RA	20.3	7.50	58.0	27.1	2.13	.13	12.0	206	31.1	535	7.30	5.73	.22	1,040	2.52	.625	5,390
SQ3-172	9,355	S	FA	3.72	7.00	57.8	27.1	2.32	.30	9.00	8.63	2.60	675	5.97	6.00	.01	1,120	2.55	.460	5,100
SQ3-173	9,360	RBI	FA	1.66	2.30	89.7	<.09	.65	.21	.48	22.7	.297	2,060	.83	.91	<.01	946	2.23	2.10	13
SQ3-178A	9,438	S	FA	3.95	7.07	61.6	24.2	2.29	.27	8.15	9.44	2.55	757	5.76	5.61	.02	1,200	2.50	.606	5,890
SQ3-178A	9,438	S	RA	66.4	11.8	64.2	28.0	2.37	.24	16.2	430	98.2	789	5.74	5.99	.38	1,070	2.60	.740	5,910
SQ3-178B	9,438	S	FA	4.02	6.91	59.5	24.8	2.20	.25	8.20	22.4	2.73	754	5.67	5.53	.02	1,090	2.52	.588	4,800
SQ3-178B	9,438	S	RA	3.57	4.88	67.4	51.6	3.84	.13	13.4	17.1	7.34	980	2.50	9.02	.05	1,360	2.96	.186	10,600
SQ3-186	9,562	LBI	FA	1.76	10.3	114	<.09	.23	.25	.76	49.5	2.88	104	1.08	.50	<.01	341	1.77	3.51	178
SQ3-189	9,598	LBI	FA	2.09	2.06	372	0.82	2.52	.23	6.04	44.9	.849	4,760	3.02	5.02	.02	2,760	9.11	.084	380
SQ3-193	9,719	S	FA	3.01	8.08	66.2	21.3	2.01	.27	7.45	9.59	2.92	713	5.40	5.17	.02	1,000	2.48	.985	4,270
SQ3-193	9,719	S	RA	77.8	14.1	68.5	24.7	2.13	.29	15.1	503	102	724	5.38	5.28	.38	960	2.51	1.25	5,260
SQ3-194	9,725	RBI	FA	3.34	32.4	60.3	0.69	2.24	.33	1.16	366	3.15	4,390	7.09	1.83	<.01	381	1.61	.876	657
SQ3-196	9,747	S	FA	3.42	8.35	66.5	19.2	2.01	.30	7.12	11.3	2.23	689	5.95	4.93	<.01	1,100	2.39	1.04	3,900
SQ3-196	9,747	S	RA	66.5	13.4	66.8	22.9	1.95	.26	13.7	473	87.8	705	5.59	5.05	.35	932	2.43	1.24	5,070

Table 4   33

≥USGS